Vol. 2 AUGUST, 1919 No. 8

Journal

—OF THE—

American Ceramic Society

A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries.

COMMITTEE ON PUBLICATIONS:

GEORGE H. BROWN, Editor
Rutgers College, New Brunswick, N. J.

L. E. BARRINGER, *Chairman*,
General Electric Co., Schenectady, N. Y.

A. V. BLEININGER,
Bureau of Standards, Pittsburgh, Pa.

H. RIES,
Cornell University, Ithaca, N. Y.

E. W. TILLOTSON,
Mellon Institute, Pittsburgh, Pa.

CONTENTS

Subject *Page*

Editorials:

Ceramic Day at the Chicago Exposition 591
New Members 592

Original Papers and Discussions:

On the Effect of Extraction upon the Plasticity of Clay—Hamor and Gill .. 594
A Machine for Testing the Hot-Crushing Strength of Firebricks—Schurecht 602
The Rapid Electrometric Determination of Iron in Some Optical Glasses—Ferguson and Hostetter 608
A Study of High-Fire Porcelains—Lin 622
The Manufacture of Abrasive Wheels—Linbarger 638
The Equipment of a Casting Plant for the Manufacture of Glass Pots—Riddle 647
Note on the Casting of Porcelain Glass Pots—Wright and Fuller 659

Ceramic Abstracts 664
Ceramic Patents 674
Summer Meeting 678
Activities of the Society 681
Acquisition of New Members during July, 1919 682

Published Monthly by the
AMERICAN CERAMIC SOCIETY

Publication Office
211 Church St., Easton, Pa.

Editorial Office
Rutgers College, New Brunswick, N. J.

SIX DOLLARS PER YEAR (Foreign Postage Additional) *SINGLE NUMBERS, SIXTY CENTS*

Entered as second-class matter, July 15, 1918, at the post office at Easton, Pa., under the Act of March 3, 1879.

Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized August 16, 1918.

Copyright, 1919, American Ceramic Society

AMERICAN CERAMIC SOCIETY.

OFFICERS, 1919-1920.

President: R. T. Stull, Bureau of Mines, Mining Experiment Sta., Columbus, O.
Vice-President: R. H. Minton, General Ceramics Co., Metuchen, New Jersey.
Treasurer: R. K. Hursh, University of Illinois, Urbana, Illinois.
Secretary: C. F. Binns, Alfred University, Alfred, New York.
Board of Trustees: The four above-named officers and E. T. Montgomery, R. D. Landrum, M. F. Beecher, G. H. Brown, and H. F. Staley.

CORPORATION MEMBERS, 1919-1920.

Abrasive Company.
American Dressler Tunnel Kilns, Inc.
American Emery Wheel Works.
American Encaustic Tiling Co.
American Terra Cotta & Ceramic Co.
American Trona Corporation.

Bausch & Lomb Optical Co.
Beaver Falls Art Tile Co.
Benjamin Electric Mfg. Co.
"Brick and Clay Record."
Buckeye Clay Pot Co.

Canton Stamping & Enameling Co.
The Carborundum Co.
Champion Ignition Co.
The Colonial Co.
Consolidated Window Glass Co.
Cortland Grinding Wheel Co.

B. F. Drakenfeld & Co., Inc.
Dunn Wire Cut Lug Brick Co.

East Liverpool Potteries Co.
Edgar Plastic Kaolin Co.
Elyria Enameled Products Co.

Findlay Clay Pot Co.
Foote Mineral Co.
Edward Ford Plate Glass Co.
The French China Co.
Frink Pyrometer Co.

Golding Sons Co.

Hall China Co.
Hanovia Chemical & Mfg. Co.
Harbison-Walker Refractories Co.
The Harker Pottery Co.
Harshaw Fuller & Goodwin Co.
Homer-Laughlin China Co.
L. J. Houze Convex Glass Co.

Illinois Glass Co.
Iroquois China Co.

Jefferson Glass Co.
Jeffery-Dewitt Co.
Johnston Brokerage Co.
Jones Hollow Ware Co.

Edwin M. Knowles China Co.
Knowles, Taylor, and Knowles Co.

The Limoges China Co.
Laclede-Christy Clay Products Co.
Lindsay Light Co.
Louthan Supply Co.

Macbeth-Evans Glass Co.
Maine Feldspar Co.
F. Q. Mason Color and Chemical Co.
Massillon Stone and Fire Brick Co.
Maxf Grinding Wheel Corporation.
Midland Terra Cotta Co.
Monongah Glass Co.
The Mosaic Tile Co.
D. E. McNicol Pottery Co.
T. A. McNicol Pottery Co.

Norton Co.

Ohio Pottery Co.
Onondaga Pottery Co.
Owen China Co.

Pennsylvania Salt Mfg. Co.
Perth Amboy Tile Works.
The Pfaudler Co.
Phoenix Glass Co.
Pittsburgh High Voltage Insulator Co.
Pittsburgh Plate Glass Co.
Potters Supply Co.

Roessler & Hasslacher Chemical Co.

John H. Sant & Sons Co.
The Saxon China Co.
The Sebring Pottery Co.
Smith-Phillips China Co.
Standard Pottery Co.
Stanley Insulating Co.
Star Porcelain Co.
Steubenville Pottery Co.
Streator Clay Mfg. Co.

The Taylor, Smith & Taylor Co.
R. Thomas & Sons Co.
C. C. Thompson Pottery Co.
Trenton Flint & Spar Co.

United States Glass Co.

Veritas Firing System.
Vitro Manufacturing Co.
Vodrey Pottery Co.

Warwick China Co.
The West End Pottery Co.
Western Stoneware Co.

COMMITTEE ON MEMBERSHIP.

R. C. Purdy, *Chairman*,
Norton Co.,
Worcester, Mass.

JOURNAL
OF THE
AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 2 **August, 1919** **No. 8**

EDITORIALS.

CERAMIC DAY AT THE CHICAGO EXPOSITION.

The Fifth National Exposition of Chemical Industries will be held at the Coliseum in Chicago the week of Sept. 22, 1919. The Exposition has become a national institution and each year sees a wonderful development in the display of chemical products and appliances and in the interest taken by the ever-increasing number of those in attendance.

Expositions in Europe are of far greater industrial significance than in the United States, but we are rapidly learning the great good to be accomplished by such an exchange of ideas and data as can be accomplished only by expositions. President McKinley once said, "Expositions are the timekeepers of progress" and we are beginning to realize the clearness and correctness of his view.

The management of the Fifth National Exposition has set aside Wednesday, Sept. 24th, as Ceramic Day and a special effort will be made on all sides to make that day of unusual interest and value to all who are interested in any branch of the silicate industries. Scattered throughout the hall will be the individual exhibits of the many companies, displaying the latest developments in the various lines of structural materials, refractories, glass, white ware, porcelain, enamels, abrasives, and the many other branches allied with the ceramic family.

Special interest will center in the ceramic program of the day. Many interesting things are promised including the following addresses and "movie" films:

Afternoon—Sept. 24th:

"Superior Refractories," by Mr. Ross C. Purdy, Norton Company, Worcester, Mass.

"Buy on Analysis," by Dr. Alexander Silverman, University of Pittsburgh, Pittsburgh, Pa.

Evening—Sept. 24th:

Film—Making of Cut Glass.

"The American Ceramic Society—Past, Present and Future," by Prof. Charles F. Binns, Alfred University, Alfred, N. Y.

Film—Manufacture of Glass.

"The Application of Scientific Methods to Ceramic Research," by Mr. A. V. Bleininger, Bureau of Standards, Pittsburgh, Pa.

This will serve to give an idea of the excellence of the program that awaits those who meet with us in Chicago. Other very interesting contributions are promised and the final program will be one of first importance to those interested in the science of the silicates.

The headquarters of the American Ceramic Society will be at Booth No. 205 in the Balcony of the Coliseum. Representatives of the Society will be in constant attendance at the Booth throughout the Exposition to assist visitors in any possible way. Make your headquarters at Booth 205 with the other ceramic men and take advantage of the facilities provided by the American Ceramic Society for your comfort and convenience.

The Chicago Section of the American Ceramic Society is making full preparations to look after the Society's interests and in all probability a dinner will be arranged at which we can all get together between the afternoon and evening sessions on Wednesday. Closer association and closer contact between the various individual interests and the various interests included in the silicate industries are the very great needs of our very large and growing family.

Let us all meet in Chicago on Wednesday, Sept. 24th.

C. H. KERR, *Chairman*, Committee on Coöperation.

NEW MEMBERS.

With the approach of Fall and cooler weather the activities of the various committees of the Society should be pursued with

new energy. The vacation period is always one of marking time and more or less disorganization. The steady upward trend of the membership-growth curve of the Society should be maintained. The increase of more than 100 per cent in membership within the past two years has been very gratifying and indicates an awakening to the necessity of the technical advancement of the industry through the coöperation of all branches of the industry.

It is imperative that each and every member of the Society lend his utmost support to the newly appointed chairman of the Membership Committee, Mr. F. H. Riddle, in his campaign for new members. After all, personal solicitation is the best means of recruiting members and unless the efforts of the Chairman are backed up by our members his efforts are apt to prove discouraging.

The large acquisition of members from the glass industry during the past two years has been very gratifying. However, this great branch of the ceramic industry has been scarcely touched and should prove an ever-increasing bulwark to the Society. There are other fields which, if thoroughly canvassed, should prove fertile sources for new members. Considerable space has been devoted in the Transactions and in the Journal to discussions of the technique of cement and the lime industries and it is to be hoped that these two branches of the ceramic industry will lend their increasing support to the American Ceramic Society. The designation of the Journal as the official technical organ of the National Lime Manufacturers' Association was a long step forward in securing the coöperation of these great industries in the work of the Society. An active campaign for recruiting members from the individuals and firms engaged in this industry should not be neglected.

Boost for new members!

ORIGINAL PAPERS AND DISCUSSIONS

ON THE EFFECT OF EXTRACTION UPON THE PLASTICITY OF CLAY.

By W. A. Hamor and H. E. Gill.[1]

An examination of the literature relating to clays shows that very little experimental work has been conducted for the purpose of ascertaining the effect of organic solvents upon that property of clay known as plasticity. Statements have been repeatedly made that the plastic properties of clays are influenced by their content of organic matter, but there has been an insignificant amount of research evidence presented, either in opposition to or in support of this theory.

The report of Otto Nolte[2] may be summarized as follows:

A heavy Silesian clay was thoroughly extracted with ethyl ether and acetone. On evaporation, a yellow mass remained which consisted of sulphur and an unidentified organic substance. Extraction did not diminish the plasticity of the clay and Nolte was unable to verify Böttcher's conclusion that this property is predominately influenced by the organic content.

The effect of organic matter upon plasticity was brought out by Böttcher. The same action was noted by E. Bourry,[3] who indicated the sources of organic matter in clay and remarked that the proportion of organic substances is not usually large but, generally speaking, tends to increase the plasticity and water-absorbing power. W. B. Davis[4] has more recently discussed the rôle

[1] The authors are indebted to Dr. E. W. Tillotson, Assistant Director of the Mellon Institute, for his courteous and suggestive interest.

[2] *Biedermann's Zentr.*, **47**, 108–9 (1918).

[3] "A Treatise on the Ceramic Industries," 28 (1911).

[4] *Trans. Am. Ceram. Soc.*, **16**, 65 (1914).

played by organic substances. Davis states that "clays are simply buried soils, or soils reworked by water, so we may expect to find these organic colloids present to some extent. Whether they are present as emulsion colloids, and acting as protective colloids, has yet to be definitely determined. We do know that many of the excessively plastic clays often contain considerable organic matter. These organic colloids and adsorbed salts tend to raise the viscosity of the water-film, hence increasing the plasticity." In view of these and other similar statements in the literature, and because of the absence of data on American clays, the authors carried out the extraction of several widely distributed samples, not with the purpose of supporting any one theory, but solely to determine the deportment of American clays after the removal of soluble organic material.

In the extractions two varieties of clays were used, namely, ball clays and fire clays. These were taken from widely separate fields, those of Mississippi, Missouri and Kentucky. A brief description and the analysis of each clay upon which the extractions were made are as follows:

First.—A white colored, fairly plastic, fire clay from the Missouri district; it is used in glass-house refractories, high-grade brick, and graphite crucibles.

Analysis.

	Per cent.
SiO_2	50.29
Al_2O_3	32.58
Fe_2O_3	0.92
MgO	1.11
CaO	1.00
TiO_2	1.44
Alkalies	1.86
Loss on ignition	10.44

Second.—A Kentucky ball clay, which possessed a brown color, very high plasticity, and exhibited cracking qualities when made into briquettes and dried. An enumeration of the uses of this type of clay would include those already mentioned, namely, glass pots and crucibles; abrasive wheels, saggers, and lead pencils may be added.

Analysis.

	Per cent.
SiO_2	51.40
Al_2O_3	33.78
CaO	1.04
Fe_2O_3	1.39
MgO	0.81
TiO_2	1.17
Alkalies	0.94
Loss on ignition	10.11

Third.—A Mississippi ball clay of the Tallahatchie County deposit, described as tough, of high plasticity, dense-burning nature, and often possessing high transverse strength. The clay of this deposit finds extensive use in the crucible and glass-pot industries and frequently as a bond in the manufacture of abrasive wheels. An analysis of the clay of the Mississippi district has not been carried out, but it has been reported to be high in silica and the iron oxide is said to run from 1.5 to 4.5 per cent.

Experimental.

The clays were ground to 80-mesh and dried over night at a temperature of 110° C. After being cooled to room temperature, a 450-gram sample was weighed out and transferred to a narrow-neck glass-stoppered bottle of $1^1/_2$ liters capacity. The next step was the addition of the solvent, exactly 500 cc. being added to each sample of clay. Care was taken to use the same amount of solvent in each experiment, so that the resulting action of each solvent on the various samples of the same clay might be comparable. After the organic solvent had been added, the bottles were each in turn placed in a shaking machine and agitated for 14 hours. Upon the expiration of this time the mass was removed immediately from the extractor and filtered. The residue was dried at 110° C over night and again passed through an 80-mesh sieve. This latter precaution, passing the clay for a second time through a sieve, was taken to make certain that the clays were in a uniform state of division, so that the change in plasticity, if any resulted, might not be due to a variation in the size of the particles.[1]

[1] The authors desire to express their appreciation of the helpful suggestions received from Mr. M. G. Babcock, an Industrial Fellow of the Mellon Institute, during the progress of this experimental work.

The organic solvents used were ethyl alcohol (95%), ethyl alcohol containing 1 per cent of HCl, commercial benzol, acetone and carbon tetrachloride. The filtrates of each were received in separate containers and were evaporated to 50 cc. on a water-bath for examination. In each case, however, the quantity of extracted matter was too small for the identification of the constituents.

Methods Used for the Determination of Plasticity.

First.—The Method of A. V. Bleininger and G. A. Loomis,[1] one of the most reliable procedures, was used as follows to determine the relative plasticities:

Water of Plasticity.—The samples were separately mixed to the point where their water contents gave to the clay a softness and pliability such that the samples could be easily worked without adhering to the hands. This was taken as the point of greatest workability. The clays were rolled into cylindrical shapes and wrapped separately in wet cloths, after which they were placed in tightly capped jars for three days. The moisture being uniformly distributed at the end of this period, each sample was ready for molding. They were each thoroughly worked and molded into briquettes of the dimensions $1'' \times 2\frac{1}{2}'' \times \frac{1}{2}''$. The weight of each briquette was determined and recorded as the wet weight. After drying at room temperature and then to constant weight at 110° C, the dry weights were determined and the water of plasticity was calculated as the ratio of the loss in weight during the drying process over the dry weight. Three determinations were made on each sample and all results recorded in the following table are the average of three similar determinations and not of one chance result.

Drying Shrinkage.—The shrinkage was determined by weighing the wet briquettes, then immediately suspending them in kerosene and again making a suspended reading. This gave the wet volume. The specimens were dried, first at atmospheric temperature, and later to 110° C. The dry weights were then determined. The briquettes were immersed in kerosene for twelve hours and the

[1] *Trans. Am. Ceram. Soc.*, **19**, 601 (1917).

dry volumes determined as before. From these determinations the data presented in Table 1 were obtained, a brief explanation of which may be given as follows:

$$a = \left\{ \begin{array}{l} \text{Volume of total water in} \\ \text{terms of true clay volume,} \\ \text{expressed in per cent.} \end{array} \right\} = \frac{100\ S\ (W - D)}{D}$$

recorded in first column, Table 1.

$$b = \left\{ \begin{array}{l} \text{Volume of shrinkage water, in} \\ \text{terms of true clay substance,} \\ \text{expressed in per cent.} \end{array} \right\} = \frac{100\ S\ (V - V_1)}{D}$$

recorded in second column, Table 1.

In the computations for which the above formulas are given:

S = specific gravity of clay, which approaches 2.60 for these types of clays.
D = dry weight of sample.
W = wet weight of sample.
V = wet volume of sample.
V_1 = dry volume of sample.
(a — b) = pore water in terms of true clay volume.
$\frac{(a - b)}{b}$ = the relation of pore to shrinkage water.
$\frac{b}{a} \times 100$ = per cent of shrinkage water in terms of the volume of total water.

Second.—The Atterberg Method[1] was also used as follows to determine the relative plasticities:

(*a*) *The Flow or Upper Boundary of the Plastic Condition.*—About five grams of the clay powder of approximately 120-mesh were put into a small porcelain evaporating dish and made into a paste by the addition of distilled water. By means of a polished nickel spatula the mass was shaped into a smooth layer, a trifle less than 1 cm. (0.39 in.) in thickness. The clay was divided into two portions by cutting a triangular-shaped channel through the mass, the lower edges being separated a trifle. The dish was then repeatedly and sharply rapped against the heel of the hand in order to bring about the flowing together of the separated portions. The flow limit was reached when the two portions of the clay could barely be made to meet at the bottom. If the paste was too thick or too thin, water or clay was added

[1] Bur. Standards Tech. Paper No. 46 (1915).

TABLE I.—EXPERIMENTAL RESULTS, METHOD NO. 1.

Type of clay.	Solvent used in extraction.	% of H_2O of plasticity $\frac{W-D}{D} \times 100$.	H_2O in terms of clay (true) volume (a).	Shrinkage H_2O in terms of true clay volume (b).	Pore H_2O in terms of true clay volume (a—b).	Ratio of % pore to % shrinkage H_2O $\frac{a-b}{b}$.	Shrinkage H_2O in terms of total H_2O $\frac{b}{a} \times 100$.	% volume shrinkage in terms of dry volume $\frac{v-v_1}{v} \times 100$.	Wet volume of samples in cc. av. of three V.	Dry volume of samples in cc. av. of three V_1.
Missouri fire clay	none	31.7	82.4	39.93	42.47	1.063	48.46	27.9	20.79	16.25
Missouri fire clay	acetone	28.0	72.8	33.17	39.63	1.195	45.56	23.8	19.82	16.01
Missouri fire clay	alcohol + 1% HCl	26.1	68.0	28.40	39.60	1.394	41.76	20.4	20.00	16.61
Missouri fire clay	alcohol	25.3	65.8	30.48	35.32	1.159	46.32	22.5	21.14	17.24
Missouri fire clay	benzol	23.1	60.1	26.30	33.80	1.285	43.76	19.6	21.42	19.90
Missouri fire clay	carbon tetrachloride	21.0	54.6	18.53	36.07	1.946	33.93	13.3	19.74	17.41
Kentucky ball clay	none	71.8	186.7	144.8	41.9	0.2894	77.56	99.20	22.28	11.18
Kentucky ball clay	benzol	66.6	173.6	131.2	42.4	0.3300	75.57	90.26	22.17	11.65
Kentucky ball clay	alcohol	65.3	169.8	130.6	39.2	0.3002	76.93	90.23	20.39	10.72
Mississippi clay	none	56.87	147.8	99.82	48.04	0.4849	67.54	65.35	20.07	12.14
Mississippi clay	alcohol	51.78	134.6	88.68	45.95	0.5181	65.93	59.99	21.50	13.44

until the proper consistency had been attained. The water content of the clay mass in this condition was then carefully determined by drying to constant weight and the value expressed in terms of percentage of the dry weight of the clay.

(*b*) *The Lower Plasticity Limit or the So-called Rolling Limit.*—Clay in the stiff plastic condition was rolled between the hands and a plain smooth surface covered with paper until slender cylindrical threads formed. These "threads" might break up into smaller lengths, but this was of no significance. Dry clay powder was added to the plastic mass and thoroughly incorporated in it, and the rolling operation repeated. The desired consistency had been attained when the clay could no longer be fashioned into threads by this method, but crumbled instead. This condition could be recognized rather sharply, and no difficulty was experienced in checking the results. The water was determined from this consistency and expressed in terms of percentage of

TABLE 2.—EXPERIMENTAL RESULTS, METHOD NO. 2.

Clay.	Solvent.	Av. upper limit.	Av. lower limit.	Plasticity number.
Missouri fire clay	none	31.31	22.76	8.55
Missouri fire clay	alcohol + 1% HCl	26.47	18.23	8.24
Missouri fire clay	alcohol	25.04	17.22	7.82
Missouri fire clay	acetone	28.21	20.74	7.47
Missouri fire clay	carbon-tetrachloride	28.41	21.78	6.63
Missouri fire clay	benzol	25.59	19.26	6.33
Kentucky ball clay	none	68.91	36.09	32.82
Kentucky ball clay	benzol	63.65	32.00	31.65
Kentucky ball clay	alcohol	63.87	33.07	30.80
Mississippi ball clay	none	51.16	25.23	25.93
Mississippi ball clay	alcohol	52.53	28.84	23.69

the dry weight of the clay. This figure subtracted from the one determined by (*a*) gives a figure which was called the "plasticity number" and the higher this value the more plastic is the clay.

By this procedure, as by the first, several determinations were made and the averages reported as shown in Table 2.

Discussion of Results.

It will be noticed, under the title column, "Solvents used in Extraction," that in each table three are marked "none." These determinations were made on the clay as it was received with no previous extraction and from these the actual plasticity of each was accurately determined. With these results the plasticity of each extracted sample was compared with that of the unextracted sample of its type.

The results show that in each extraction there was a diminution which was established by one method and checked by the other. It will be seen from the tables that the two determinations agree rather closely. While the extent of change does not agree by both methods, the results are comparable. Upon the Missouri clay the three solvents having greatest effect were alcohol, alcohol containing 1 per cent of HCl, and acetone. These three are grouped together in both determinations; in Table 1 the acetone extraction stands first as having the least effect, while in Table 2 it is third, with alcohol and alcohol containing 1 per cent of HCl retaining their same relation to each other. The carbon tetrachloride extraction and that of benzol check very closely, notwithstanding that they alter places with each other.

In the results on the Kentucky ball clay it will be seen that they retain the same relation to the unextracted sample by both the Bleininger and Loomis and the Atterberg methods.

Summary.

The results obtained may be summarized as follows:

1. Certain clays after being treated with organic solvents are less plastic than the original materials.

2. The degree of lowering of the plasticity is not the same for different solvents.

MELLON INSTITUTE OF INDUSTRIAL RESEARCH,
PITTSBURGH, PA.
July 10, 1919.

A MACHINE FOR TESTING THE HOT-CRUSHING STRENGTH OF FIREBRICKS.[1]

By H. G. Schurecht.

Introduction.

In testing refractories under load, Bleininger and Brown[2] applied a constant load of 25–50 pounds per square inch on firebricks and after heating to a constant temperature (1150–1500° C) measured the deformation.

Mellor and Moore[3] tested fire-clay brick by applying a constant load and increasing the temperature until the brick deformed a fixed amount and used this "squatting" temperature as a means of comparing fire clays.

Shaw[4] used a compressed spring to apply the load—in which case the load increased as the brick expanded and decreased as the brick contracted—his claim being that this test brought the conditions closer to those encountered in practice.

After freely consulting the works of these authors a machine was designed by the Bureau of Mines with which the hot-crushing strength can be measured in addition to the deformation under a constant load. The strength test is of value in differentiating between silica, magnesite, chrome and high-grade fire-clay bricks when heated from 1300–1500° C. It is also of value for testing lower-grade refractories at low temperatures; for testing sagger bodies; and for measuring the strength of fire-proofing materials at various temperatures.

Description of Testing Machine.

The furnace (Figs. 1 and 2) is fired by two tangential air-gas burners. It is capable of testing two bricks at the same time and can be controlled by one operator.

[1] By permission of the Director, U. S. Bureau of Mines.

[2] A. V. Bleininger, and G. H. Brown, *Trans. Am. Ceram. Soc.*, **12**, 337–369 (1910); Report of Committee C-8 on Refractories, *Proc. Am. Soc. Testing Materials* (1918).

[3] J. W. Mellor, and B. J. Moore, *Trans. Eng. Ceram. Soc.*, **152**, 117–130 (1915–1916).

[4] J. B. Shaw, *Trans. Am. Ceram. Soc.* **19**, 498–506 (1917).

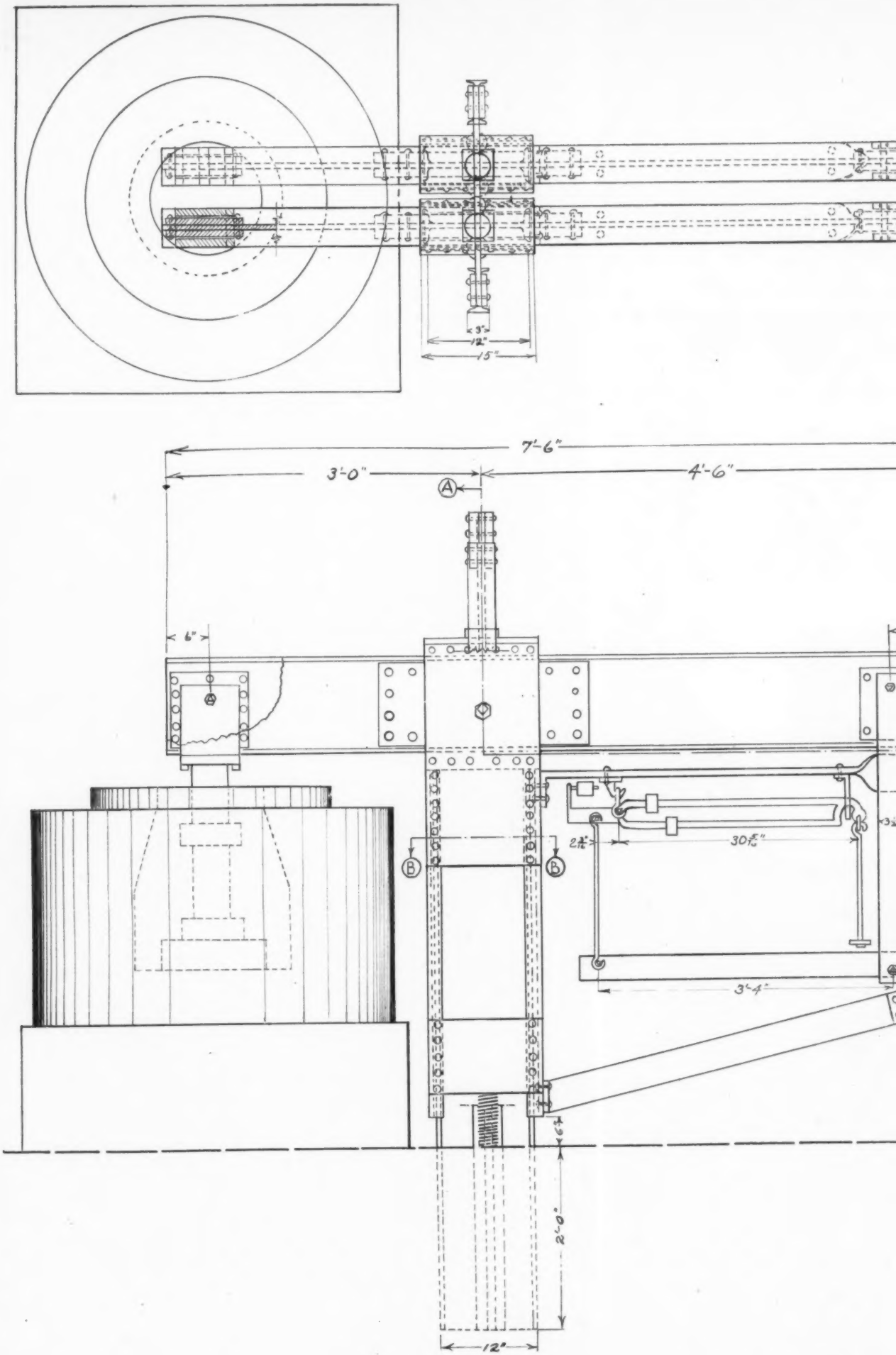
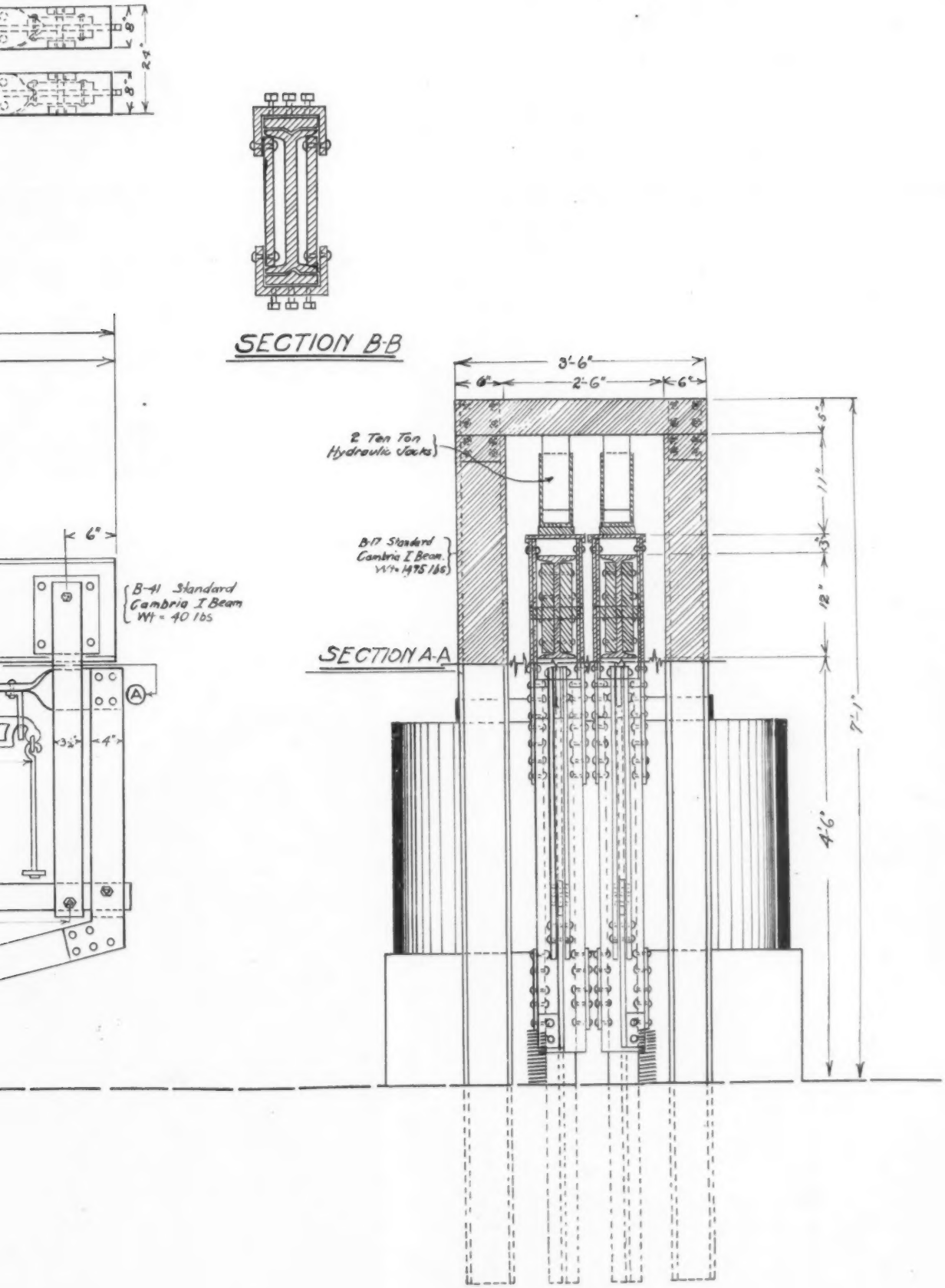


FIG. 1.


8"
24"
8"
SECTION B-B
3'-6"
6"
2'-6"
6"
2 Ten Ton
Hydraulic Jacks
B-17 Standard
Cambria I Beam
Wt = 1975 lbs
6"
B-41 Standard
Cambria I Beam
Wt = 40 lbs
SECTION A-A
A
3½"
4"
5"
11"
3"
12"
4'-6"
7'-1"

IG. 1.

In testing a fire-clay brick at temperatures above 1200° C, the brick deforms considerably before the final failure occurs. It was therefore necessary to design a machine that would take care of this deformation without tilting the main test-beam—as this would cause shearing of the brick and a premature failure. This is accomplished by moving the whole testing machine down

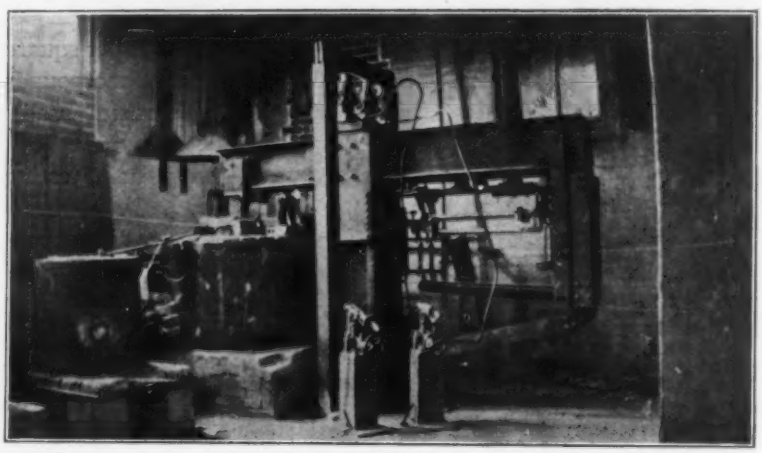


FIG. 2.

as the brick deforms. Each machine operates independently of the other and both are guided in a straight up-and-down movement by means of four slides which fit in V-shaped lateral grooves in stationary vertical I-beams. When no pressure is applied, the machine is supported by means of springs (see Fig. 1).

Method of Testing Brick.

The brick are subjected to a load of 25 pounds per square inch while the temperature is being increased to the desired point. The final temperature is varied in testing different materials as follows:

For fire-clay brick	1300° C
For magnesite brick	1350° C
For chrome brick	1350° C
For silica brick	1500° C

In each case the heating curves recommended by the American Society for Testing Materials[1] are used. At the end of the heating, the load is increased by applying pressure by means of two Watson-Stillman hydraulic jacks until the brick fails—the load then being measured by keeping the scale-beams balanced. The use of an automatic scale in the place of the scale-beam makes the measurement of the load much simpler.

The machine is accurate to 5 pounds per square inch—an accuracy of 1.6 per cent for minimum loads of 25 pounds per square inch on a standard brick, or 0.2 per cent for a load of 200 pounds per square inch (which is about the average pressure used). The safe maximum load for each machine is 8000 pounds.

By means of an Ames dial placed against the main testing beam, the expansion and contraction of the brick may be measured throughout the test. Corrections are made for the expansion of the plungers but the expansion thus recorded is only approximate, owing to the expansion of the furnace bottom.

Results of Tests.

The results of tests are shown in Figs. 3, 4, 5, 6 and 7. The silica brick marked "Ohio" was made of flint from near Flint Ridge, Ohio, while the one marked "Pennsylvania" was made from a Pennsylvania silica. Although the expansion of the Ohio brick was greater than that of the Pennsylvania brick, it stood a better load test. The Ohio brick, however, was only burned to cone 14 and if it had been burned to cone 18 the expansion would probably have been less.

The expansion of the silica and magnesite bricks was greater than that of the chrome and fire-clay bricks. There was a large increase in the expansion of the silica brick when the temperature on the outside of the brick was 300° C—probably due to the temporary conversion of cristobalite[2] from the alpha to beta form. The expansion of the magnesite brick was much more gradual with increase in temperature.

[1] *Loc. cit.*

[2] LeChatelier and Bogitch, "The Manufacture of Silica Brick," *Bull. Am. Inst. Mining Eng.*, **141**, 1438 (1918); J. Spotts McDowell, "A Study of Silica Refractories," *Bull. Am. Inst. Min. Eng.*, **119**, 2007 (1916).

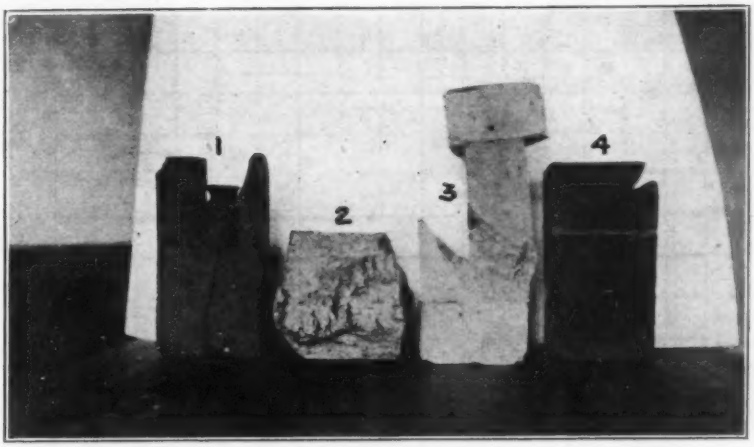


FIG 3.—Bricks after testing: (1) Magnesite. (2) Fire-clay. (3) Silica. (4) Chrome.

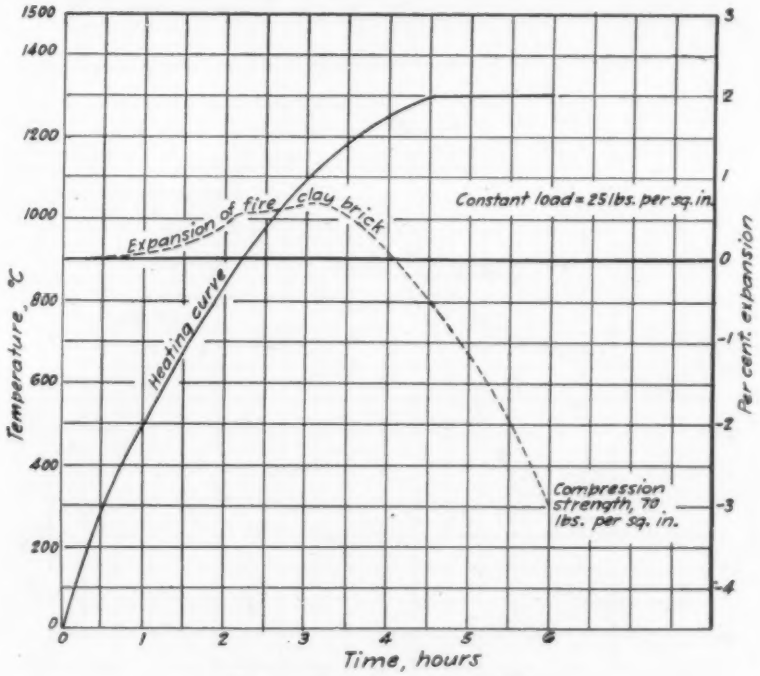


Fig. 4.—Tests on fire-clay brick.

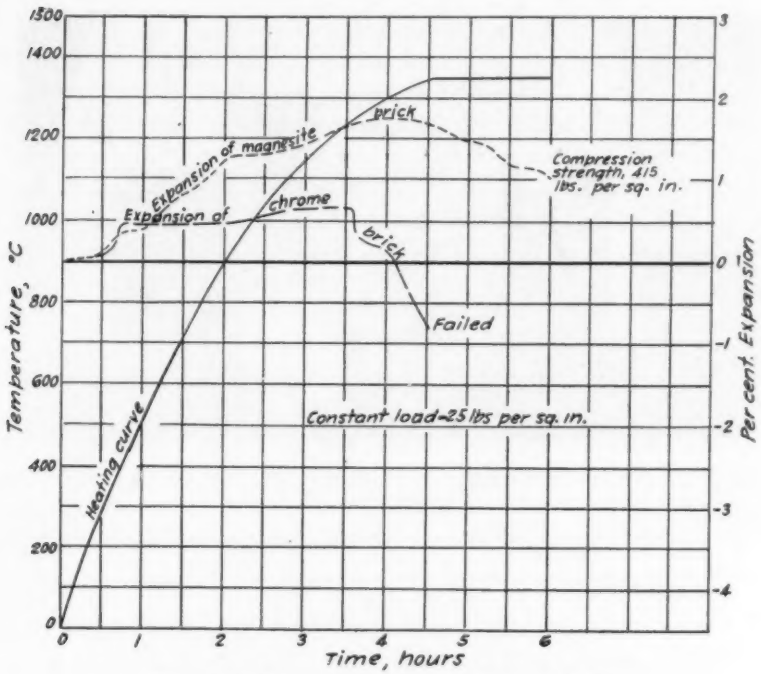


Fig. 5.—Tests on magnesite and chrome bricks.

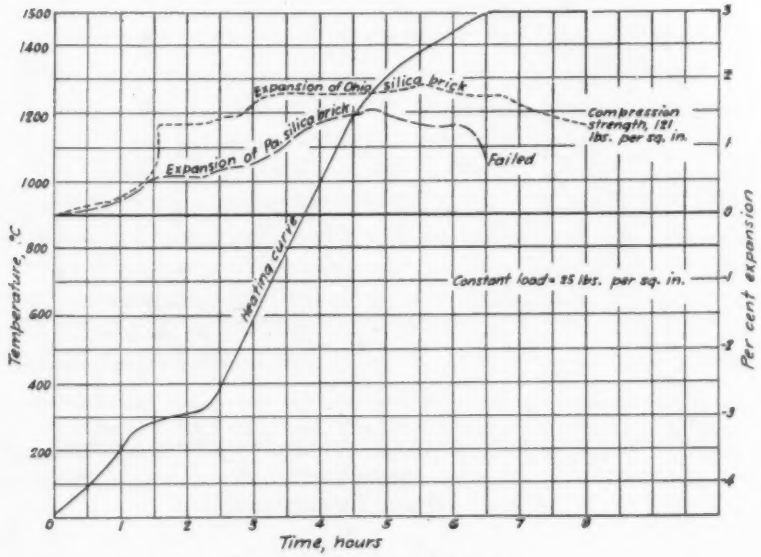


FIG. 6.—Tests on silica bricks.

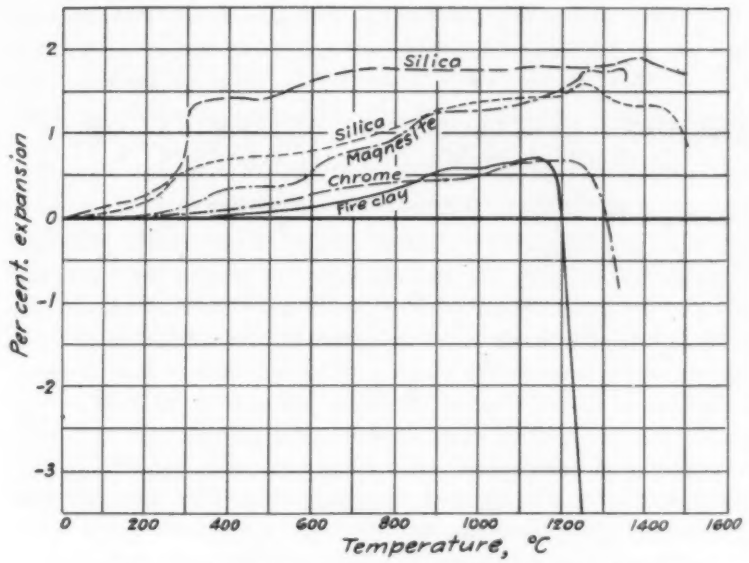


Fig. 7.—Expansion of refractory bricks during load test.

The silica and magnesite bricks show the least deformation while the fire-clay and chrome bricks show the greatest (see Fig. 3).

MINING EXPERIMENT STATION,
BUREAU OF MINES,
COLUMBUS, OHIO.

THE RAPID ELECTROMETRIC DETERMINATION OF IRON IN SOME OPTICAL GLASSES.

By J. B. Ferguson and J. C. Hostetter.

In the early stages of the development of the optical glass industry in this country, the determination of iron in the materials used, and produced in that industry, was one of the most important chemical analyses made, and was carried out on all raw materials, and frequently also on the glasses. The amounts of iron present in the glasses ranged from 0.01 to 0.02 per cent in the best heavy flints to 0.3 per cent in some experimental glasses, and at times, for purposes of comparison, an accuracy of 0.002 per cent in the determination of this element was desirable. This accuracy can be obtained upon ten-gram samples by the methods based upon the decomposition of the glasses with sulphuric and hydrofluoric acids and subsequent titration of the iron with potassium permanganate, but the use of sulphuric acid solutions necessitates many time-consuming precautions which may not be considered disadvantageous in a complete analysis of a glass with its manifold manipulations, but which should be eliminated if possible when many single determinations for factory control are desired. Fortunately at the time when a need for a more rapid method arose, an investigation of the use of the electrometric method for the determination of the end-points in the stannous chloride-potassium dichromate iron titration was nearing completion at the Geophysical Laboratory and the method was at once applied, first to sands,[1] later to the other raw materials, and finally to the glasses. The information obtained in the last application is presented in this paper.

The description of the electrometric method is in course of publication[2] but for clarity a few details will be repeated here. The principle is simple; the iron, in acid solution, is first reduced

[1] J. B. Ferguson, *J. Ind. Eng. Chem.*, **9**, 941 (1917).

[2] J. C. Hostetter and H. S. Roberts, *J. Am. Chem. Soc.* (Sept. No.)

by stannous chloride and then titrated with potassium dichromate, plotting the electromotive force against the volume of the oxidizer instead of using the inaccurate outside indicator.[1] The curve so obtained undergoes two inflections, the first upon the complete oxidation of the excess stannous chloride, and the second when the iron has similarly become all oxidized; from the location of these inflections the amount of the dichromate used up in the oxidation of the iron may readily be found. A typical curve which indicates the titration of the ferrous iron initially present in the glass in addition to the total iron is shown in Fig. 1. The method provides an accurate means of determining the

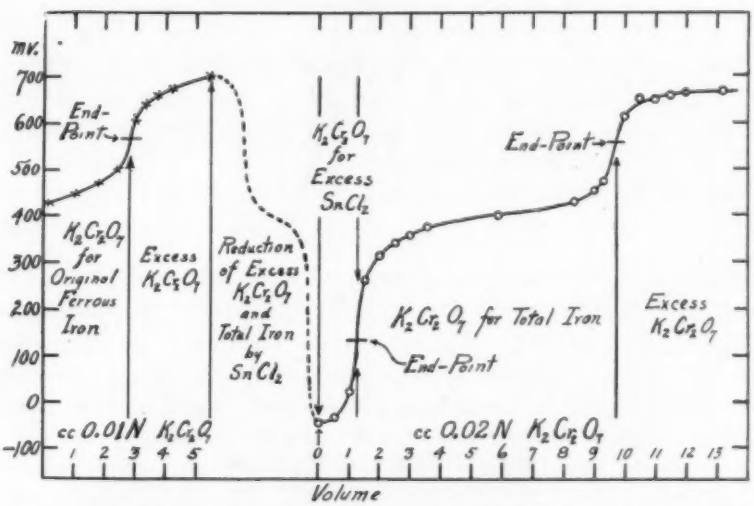


FIG. 1.—Typical curves obtained in the electrometric determination of ferrous and total iron in an experimental glass.

end-points and makes available for accurate work the dichromate titration with its many advantages over the permanganate titration, not the least of which is the use of hydrochloric acid solutions.

[1] Forbes and Bartlett have shown that the use of potassium ferrocyanide as an outside indicator in the dichromate titration may cause an appreciable error. *J. Am. Chem. Soc.*, **35**, 1527 (1913).

The titration is carried out in a flask covered by a "titrating head" which serves the dual purpose of permitting the titrations to be carried out in a current of inert gas and of supporting the calomel half-cell and platinum electrode (see Fig. 2). The elec-

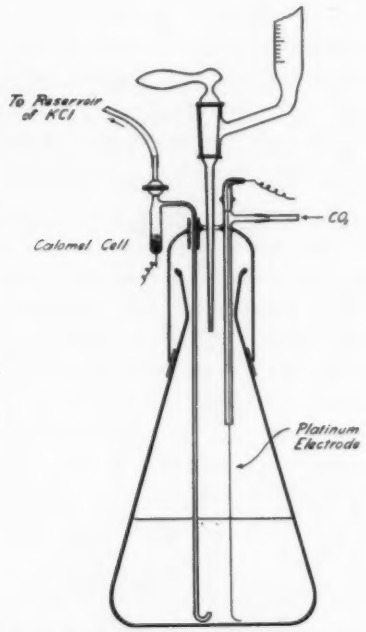


FIG. 2—Flask with "titrating head" in place. The latter carries the electrodes and acts as a cover for the flask during titration.

tromotive force developed is read on a simplified potentiometer designed by Roberts,[1] or by the method used by Hildebrand.[2]

Interfering Substances in the Glasses.—The optical glasses investigated by us were of the following types: Alkali-lead flint, borosilicate crown, light crown and barium crown, and con-

[1] To be described later.

[2] J. Hildebrand, *J. Am. Chem. Soc.*, **35**, 847–871 (1913).

tained only arsenic and boric acid among the substances which might be considered possible interfering substances. Antimony and manganese were not present. Arsenic is, however, reduced to the metal in hot concentrated hydrochloric acid solution by stannous chloride and consequently did not interfere with the determination of total iron. On the other hand, arsenic in the arsenious condition is oxidized by dichromate and therefore interferes with the accurate determination of ferrous iron.[1] Tests carried out on ferric chloride solutions indicate that boric acid also does not interfere; titrations of 6.1 and 6.0 cc. of 0.005 N $K_2Cr_2O_7$ were obtained in two experiments which were identical in all respects but one, namely, the addition of one gram of boric acid to one solution.

Preparation of Samples.—Samples should be pulverized with iron-free utensils such as an agate mortar and pestle. For the preliminary crushing the use of a brass cylinder[2] which loosely fits the pestle materially aids the process and reduces the flying of the glass fragments to a minimum. A powder which will pass 100 mesh is satisfactory.

Hydrofluoric Acid.—Hydrofluoric acid is generally considered responsible for the unsatisfactory end-point often obtained when a permanganate titration is carried out in its presence. To test its effect upon the dichromate titration the following experiments were made. The ferrous iron was determined by titration in solutions containing 100 cc. of 1 : 1 hydrochloric acid, 5 cc. dilute ferrous iron solution, and various amounts of 48-per cent hydrofluoric acid. The solutions were kept in flasks which had by test been shown to yield no appreciable ferrous iron to such solutions under more severe conditions than existed in these experiments and the titrations were made in the cold. The results are given in Table 1.

[1] Smooth curves are obtained when solutions of ferrous iron and arsenious arsenic in 1 : 1 HCl are titrated electrometrically. This is in accord with the well-known ability of certain ferrous salts to reduce arsenic in the higher (arsenic) state of oxidation in hydrochloric acid solution.

[2] Our standard laboratory practice.

TABLE 1.

Cc. 48% hydrofluoric acid added.	Cc. 0.01 N $K_2Cr_2O_7$ solution.
0	6.7
5	6.9
10	6.9
15	6.9
25	7.0

These results indicate that in the cold the acid is without effect. In hot solutions such as were used in the analyses of glasses there was frequently a drifting end-point and since its irregular occurrence precluded the placing of the blame for it upon the acid itself, we were led to believe that there must at times be some impurity in the acid capable of being oxidized in hot hydrochloric acid solution by dichromate. The nature of this impurity is somewhat obscure but may well be organic[1] and volatile, because when the acid in question was evaporated alone in platinum no residue remained, but when evaporated with sulphuric acid an appreciable carbonaceous residue was usually obtained. The so-called C.P. hydrofluoric acid usually carries this impurity, so that its presence must be considered in any procedure that is to be of general use.

Glassware Tests.—Good analyses may be carried out in glass vessels in the place of platinum if pure hydrofluoric acid is available. This is possible because the rate of attack of any reagent, as for instance hydrofluoric acid, upon a glass powder,[2] is much more rapid than upon the vessel used as a container, and this is especially true when powdered optical glass is decomposed in flasks of chemically-resistant glass. For this purpose, however, the glass vessel most resistant to hydrofluoric acid would naturally be chosen, and to enable us to make a proper selection the following tests were made:

In each of three Erlenmeyer flasks of identical size (Jena, Fry and Pyrex) were placed 25 cc. of 1 : 1 hydrochloric acid, 5 cc. of

[1] The acid did not behave as though impurities such as sulphur dioxide, arsenious acid, etc., were causing the trouble. See "A Treatise in Quantitative Inorganic Analysis," J. W. Mellor, p. 463, (1913).

[2] Compare the rates of attack found by J. H. Davidson and W. E. S. Turner on glass powders consisting of differently-sized particles. *J. Soc. Glass Tech.* **11**, 284 (1918).

48-per cent hydrofluoric acid and 0.5 cc. of concentrated sulphuric acid and the flasks were set on a hot steam bath for twenty minutes. The solutions were then removed from each flask, separately evaporated in platinum to remove the hydrofluoric acid, taken up in 150 cc. of 1 : 1 hydrochloric, acid and the iron electrometrically titrated after reduction with stannous chloride. The iron (Fe) values obtained were Jena 1.92 mg., Fry 1.85 mg., and Pyrex 1.26 mg., indicating the superiority of Pyrex over the other two types in this respect. These tests were intended as comparative tests and not intended to be in the nature of blank determinations and were purposely carried out under conditions of much greater severity than those existing during an analysis. However, a blank determination for ferrous iron was made subsequently on a Pyrex flask and gave a negligible result.

Analyses in Glassware.—The analyses in glassware were carried out by first decomposing the glass in a Pyrex Erlenmeyer flask and then reducing the iron and titrating in the same flask without the removal of any precipitate which may have formed. In this manner the determination could be carried out in less than ten minutes and the procedure was applicable to those glasses such as flints, borosilicates and crowns which are either completely soluble in a mixture of hydrochloric and hydrofluoric acids or form insoluble precipitates which carry no appreciable quantities of iron. The procedure necessitates the use of pure acids or at least acids upon which definite blank determinations could be made, and usually a slight excess of glass powder was used which insured a minimum attack upon the flask. Comparative results upon an experimental light flint glass analyzed in glassware and also in platinum ware are as follows: In glassware 0.110 and 0.109 per cent iron (Fe), and in platinum ware 0.111 per cent iron (Fe). Most of the C. P. hydrofluoric acid which we obtained was too impure to be used with this procedure for accurate work, but served for the determination of the approximate value of the iron content if the titrations were rapidly carried out since the iron reacted with the dichromate much more rapidly than did the impurity carried by the hydrofluoric acid and thus made possible the locating of the end-point approximately. The curves A and

B, given in Fig. 3, are typical of the effect of this impurity; curve C is a normal curve.

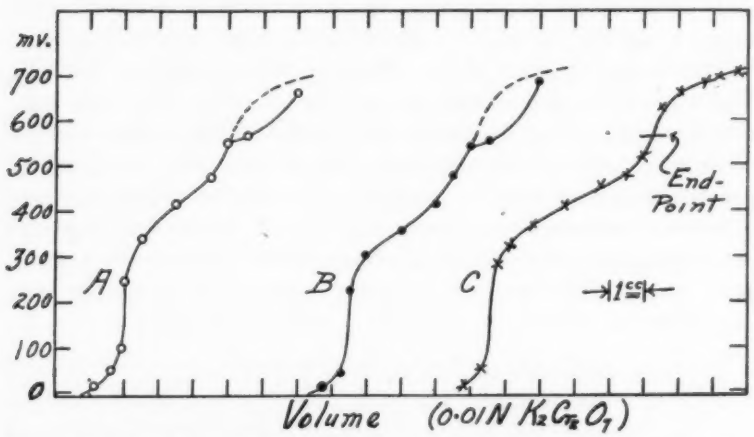


FIG. 3—Titration of total iron. Curves A and B are the result of impurity in hydrofluoric acid used in decomposing the glass. Curve C is a typically normal curve. The end-points for A and B can still be located within a small error.

Platinum Ware.—The platinum used by us was of the purest grade imported before the war. Ordinary platinum as a rule carries an appreciable amount of iron and cannot be expected to yield a constant blank. For this reason only the purest platinum should be used, thus rendering negligible any errors due to the variable amounts of iron obtained from the platinum during different analyses.

Retention of Iron by Precipitates.—The retention of iron by the insoluble salts formed during the decomposition of a glass may be a source of serious error. Allen and Zies[1] state that in some cases as much as 50 per cent of the iron may be so retained. The following analyses confirm their observations. These analyses were made upon a series of light flint glasses which were decomposed with hydrofluoric and sulphuric acids.

[1] *J. Am. Ceram. Soc.*, **1**, 739 (1918).

TABLE 2.

Retention of Iron by Lead Sulphate Precipitated in the Decomposition of Light Flint Glasses.

Glass No.	Total Fe.	Fe in lead sulphate.	Per cent total iron in lead precipitate.
43–1	0.105	0.043	41
43–3	0.193	0.117	61
43–4	0.032	0.003	9
43–5	0.099	0.072	73
45–3	0.179	0.049	27
45–6	0.150	0.091	60

The retention of iron (especially ferric) by barium and lead sulphates has been known for some years.[1] Our results given in Table 2 are of interest chiefly because of the variability in the amount of iron so retained. There was some evidence that indicated that this variability was due to the heat treatment of the precipitates inasmuch as more iron was held in those cases in which the solutions were evaporated to dryness than in those in which the evaporation of the sulphuric acid was not carried so far. Lead chloride, on the contrary, was invariably found to be free from even traces of iron, as might have been expected from the crystalline nature of this precipitate.

Total Iron.

The procedures which follow were used by us in some hundreds of glass analyses. The retention of iron by barium sulphate made necessary a separate procedure for glasses containing barium, and procedure (4) was used in place of procedures (2) and (3) when barium glasses were being analyzed. Procedure (1) was not used by us for these barium glasses because of lack of pure hydrofluoric acid. Since barium fluoride is known to be soluble in strong acids,[2] there is no good reason why this procedure should not give good results with these barium glasses.

Procedure (1).—For accurate work pure acids are required. Place 10 g. of glass powder in a Pyrex Erlenmeyer flask and cover

[1] Many references to this subject may be found in J. W. Mellor's, "A Treatise on Quantitative Inorganic Analysis," p. 611 (1913).

[2] Abegg's *Handbuch der Anorganische Chemie* **11**, 2, p. 245.

with 25 cc. 1 : 1 hydrochloric acid. Add not quite enough hydrofluoric acid to decompose all the glass (the amount of hydrofluoric acid required may be calculated approximately and later determined more accurately by test). When the reaction ceases, add enough strong hydrochloric acid to bring the volume to about 150 cc. and the acid concentration to a little above the 1 : 1 ratio and then heat to boiling, reduce with stannous chloride, cool a few seconds and titrate electrometrically with 0.01 N dichromate. Wash several times by decantation with hot water[1] any particles of glass which may have escaped decomposition, transfer to suitable dish, dry over flame, weigh roughly and deduct the weight from the initial weight of charge. The whole operation can be carried out in less than ten minutes.

Procedure (2).—For accurate work with impure hydrofluoric acid. Place 5 g. of glass powder in a platinum dish and moisten with 5 cc. of 1 : 1 sulphuric acid. Add cautiously, a little at a time, 10 to 15 cc. concentrated (48%) hydrofluoric acid. Care must be taken in this operation lest a violent reaction take place and cause a loss of much of the sample. When the reaction has apparently ceased, heat, at first gently and then more strongly, until the sulphuric acid fumes copiously and any organic matter present is decomposed. For this evaporation a Hillebrand radiator[2] may be used to advantage. We used a simpler and cheaper device which worked very satisfactorily. The platinum vessel was placed upon a nichrome triangle which was fitted with silica protecting tubes and the arms of the triangle were bent so that the vessel was held the desired distance above an electric hot plate. Around the triangle and crucible was placed an alundum or similar ring 5–8 cm. in height. After the sulphuric acid has fumed copiously for a few minutes the platinum dish is set aside to cool, and when cold its contents are taken up in 150 cc. of 1 : 1 hydrochloric acid and the iron determined electrometrically in this solution.

Procedure (3).—It sometimes happens when procedure (2) is

[1] This will remove any precipitated lead chloride which may be present.

[2] W. F. Hillebrand, "The Analysis of Silicate and Carbonate Rocks." U. S. Geol. Surv. *Bull.*, **422**, 31 (1910).

used that the organic matter does not coagulate but is suspended in the hydrochloric acid solution in such a fine state of subdivision that it is able to reduce the dichromate and thereby be a source of error. To avoid this, the contents of the platinum dish may be dissolved in just enough hot 1 : 1 hydrochloric acid to prevent the precipitation of the sulphates. This solution is cooled and the insoluble chlorides filtered off and washed several times with cold water. To the filtrate is added a few cc. of 0.1 N alum solution and the alumina and iron are then precipitated hot with ammonia. The iron and alumina are filtered off, washed with hot water and then dissolved with hydrochloric acid from the filter. The hydrochloric acid solution thus obtained is used for the titration. The organic matter either runs through the filter when the iron and alumina are being filtered, or is left on the filter when these are dissolved. The alumina gives more bulk to the precipitate and if but a little is used materially assists in the operation. Suitable blanks must, of course, be made.

Procedure (4).—Since barium sulphate is not appreciably soluble in hydrochloric acid, the iron in this sulphate is lost if procedures (2) or (3) are used with glasses containing barium. The glass may be decomposed as in procedure (2) and the contents taken up in hydrochloric acid as in procedure (3), with the exception that enough acid is used to dissolve and prevent the precipitation of the sulphates other than barium. The solution is filtered hot and the precipitate washed with hot water. The filtrate is cooled and again filtered. This second filtrate contains part of the iron and little, if any, lead or barium. The rest of the iron is in the barium sulphate. The barium sulphate precipitate is ignited in a platinum crucible, fused with sodium carbonate, leached with water, filtered and washed.[1] The sulphuric acid is thus separated from the barium and iron and these are dissolved in hydrochloric acid. The iron from the glass is thus obtained in two acid solutions which can be used for an electrometric titration. They cannot

[1] According to W. F. Hillebrand, when sulphur is determined in rocks by first fusing with sodium carbonate and then leaching with water, a very little iron is to be found in the filtrate with the sulphates. (U. S. Geol. Surv. *Bull.*, **442**, 139 (1910). In our experience with procedure (4) the amount of iron in the filtrate was always negligible.

be mixed, else the barium would again be precipitated as sulphate and might remove some of the iron. The titration may be carried out directly, or the iron may be precipitated as in procedure (3), although this would not be necessary in the case of the iron from the barium sulphate, but might be in the case of the other solution.

Ferrous Iron.—Ferrous iron may be determined in glasses provided no other reducing material is present. For this purpose the following procedure was devised, based upon the experiments given earlier in this paper, which showed that hydrofluoric acid and the impurity it usually carries do not react with 0.01 N solutions of dichromate in the cold.

Procedure: 10 g. of the glass powder (glasses other than barium crown) are placed in a Pyrex Erlenmeyer flask with 50 cc. 1 : 1 hydrochloric acid and the acid boiled to expel all air from the glass. The flask is then covered with a funnel through which a glass tube is inserted and by means of which nitrogen or carbon dioxide (freed from oxygen) can be passed through the flask. After the air has been expelled from the flask, 20 cc. of hot concentrated hydrofluoric acid which has previously been boiled for a few minutes to expel the air is added. A violent reaction takes place, and care must be exercised if an accident is to be avoided at this stage. As soon as the reaction is over, enough freshly boiled hydrochloric acid is added to bring the volume to 150 cc. and the acid concentration to a 1 : 1 value. The solution is then cooled in the atmosphere of nitrogen. When cold, the funnel and tube are removed quickly and the titration head inserted in their place. The titrations are then carried out. With the barium crown glasses the procedure is slightly modified because this glass is slightly decomposed by strong hydrochloric acid. The glass powder is first moistened with water (25 cc.) and no acid is added until all the air has been expelled by boiling for some minutes.

Blank Determinations.—The necessity for careful blank determinations is so apparent that it need not be stressed here. A true blank for the total iron determinations would require the use of an iron-free glass or silica powder. This we did not have, and with procedures (2), (3) and (4) we substituted, for the blank,

the iron value obtained when the procedure was carried out without a glass powder. The blank usually obtained in this manner amounted to from 0.2 to 0.5 cc. of 0.01 N dichromate, although in a few cases the hydrofluoric acid carried sufficient iron to materially raise these figures. The blank with procedure (1) was this blank minus the iron value obtained when the sulphuric acid alone was evaporated in platinum and the residue taken up in hydrochloric acid and titrated electrometrically, from which the hydrochloric acid blank had previously been taken. With our pure platinum we found practically the same blank for procedures (1), (2), (3) and (4).

The chemicals and glassware used in the ferrous iron determinations gave no appreciable titration with dichromate, a fact previously mentioned under the discussion of the ferrous iron determination.

The procedures previously outlined were frequently used by us during the years 1917 and 1918 and some of our results have already been published.[1] Our results upon the ferrous iron content of glasses have not previously been published, nor do we find any record of any one having attempted such analyses in the past. It is true that several investigators[2] have studied the relation between the total iron content and the color of certain glasses, and therefore it is the more surprising that no previous attempts have been made to determine the ferrous iron content since the green color so often obtained in many glasses containing much iron is generally ascribed to this ferrous iron. The ferrous iron content of good optical glass is so minute a quantity that any investigation of the relation of ferric and ferrous iron to the transmission of such optical glasses must be carried out upon special glasses containing appreciable quantities of iron. A number of these special iron-bearing optical glasses which had been prepared, were analyzed by us for both ferric and ferrous iron. The relative amounts of ferrous iron were found to vary considerably with the composition of the glass and with several other

[1] Hostetter, Roberts and Ferguson, *J. Am. Ceram. Soc.*, **2**, 356–372 (1919).

[2] C. Dralle, *Chem. Ztg.*, **24**, 1132–6 (1900); R. Zsigmondy, *Ann. d. Phys. u. Chem.*, [4] **4**, 60 (1901).

factors which need not be gone into here but which will be treated in a subsequent paper dealing with these glasses. A few representative analyses will be cited as indicative of the order of magnitude the ferrous iron content may assume in iron-bearing glasses.

TABLE 3.

Total and Ferrous Iron Found in Some Experimental Glasses.

Glass No.	Type of glass.	Total iron as Fe.	Ferrous iron as Fe.	% of total Fe which is in ferrous form.
43–1.....	Light Flint	0.103	0.0112	10.8
43–5.....	Light Flint	0.098	0.0117	12.0
43–6.....	Light Flint	0.101	0.0078	7.7
45–2.....	Light Flint	0.099	0.0207	20.9
45–5.....	Light Flint	0.110	0.0168	15.3
43–2[a].....	Light Flint	0.157	0.0224	14.3
		0.158		
		0.197	0.0241	12.3
41–1.....	Barium Crown[b]	0.138	0.0117	8.5
61–1.....	Barium Crown	0.136	0.0148	10.9
41–2.....	Barium Crown	0.229	0.0334	14.6
61–2.....	Barium Crown	0.230	0.0319	13.8
73–2.....	Barium Crown	0.214	0.0816	38.2
73–4.....	Barium Crown	0.073	0.0280	38.3
49–3.....	Ordinary Crown[b]	0.068	0.0047	6.8
49–4.....	Ordinary Crown	0.078	0.0054	7.0
49–1.....	Ordinary Crown	0.170	0.0109	6.3
85–2.....	Ordinary Crown	0.067	0.0109	16.3
85–5.....	Ordinary Crown	0.125	0.0319	25.5

a The first three determinations (two ferric and one ferrous) upon glass 43–2 by Ferguson and the last two by Hostetter upon different pieces of glass from the same thread-pot.

b The values given for the iron in the ferrous condition in the barium crown and ordinary crown glasses may include some arsenious arsenic due to the presence of this element in these glasses, which were prepared upon the assumption that in glasses all the arsenic exists in the arsenic condition. Allen and Zies have since shown that some arsenic may be present in the arsenious condition. (See *J. Am. Ceram. Soc.*, 1, 739–86 (1918).)

Summary.

The results of the application of the electrometric determination of iron with stannous chloride and potassium dichromate are discussed in this paper. The electrometric method enables one to

make rapid and accurate analyses for both ferric and ferrous iron provided interfering substances are absent. Under favorable conditions such an analysis can be made in ten minutes and may be carried out in glassware. Four different procedures are described for total iron and one for ferrous iron. A number of analytical results, including many ferrous iron determinations, are given. The ferrous iron content of the glasses proved to be dependent upon a number of factors and in some cases reached values in excess of 35 per cent of the total iron present.

GEOPHYSICAL LABORATORY,
CARNEGIE INSTITUTION OF WASHINGTON,
WASHINGTON, D. C.
July, 1919.

A STUDY OF HIGH-FIRE PORCELAINS.

By Chi C. Lin.

The rapid growth of the American chemical-porcelain industry, as a result of the World War, has given an impetus to the American clay manufacturers generally and is of good omen—particularly to the domestic production of all kinds of high-fire porcelains. That this problem holds the important place in the field of ceramic researches it really deserves is evident from the recent augmentation of technical literature on the subject. This investigation was undertaken with the hope of contributing some useful data regarding certain porcelain bodies fired to a comparatively high temperature.

A study of true porcelains, as manufactured in China, Japan and continental Europe, brings out the fact that the greatest manufacturing losses are due to sagging or distortion of the ware in firing. The practice of maturing glaze and body together makes the proper supporting of the ware during the vitrification stage very difficult, as the glaze adheres to any support and the points of contact appear as faults in the finished ware. Excessive warping is prevented to some extent by placing each article in a separate setter, but the cost of production is thus materially increased and the difficulty only overcome in part.

In the manufacture of most American china, the desired vitrification is secured in the bisque burn, during which the ware is embedded in sand, ground kaolin, or flint. Thus supported, the ware attains the necessary degree of vitrification without excessive warping. The glaze is then applied and matured at a temperature (generally not exceeding cone 5) sufficiently below the vitrification temperature of the body so that no danger of warping is encountered in the second or glost burn. However, the degree of translucency noted in the true porcelains of Europe and Asia is not obtained in the softer-fired wares of the United States. Moreover, the glazes used on the soft-fired porcelains are less

desirable on account of their inferior hardness. They also possess smooth, glossy surfaces which are not so attractive as the egg-shell surfaces of the high-fire true porcelain glazes.

The question of producing a high-fire porcelain by a modification of the American method, that is, by raising the glost temperature to permit the use of a hard-porcelain glaze, seems to offer promise, because, thereby, the danger of warping can be reduced to a minimum, while the desired translucency and glaze texture can also be secured. To accomplish this, the body must be of such composition that it will mature at relatively the true porcelain temperature—at least cone 13. This is the minimum temperature at which crystalline sillimanite forms in quantity in porcelains and, we are told, produces the fine blue-white translucency of the true porcelain. If the glaze be applied and matured at the necessary temperature it will then bring out its beauty. This glaze must be of the true unfritted porcelain type, free from lead oxide, the maturing temperature being safely below that at which the body will begin to distort. Its composition must also be such as to warrant a satisfactory glaze-fit.

The first problem is, therefore, to produce a body having excellent working qualities in the plastic state and one which will mature with the minimum amount of warping at a temperature sufficiently high to secure the desired translucency. The second problem is to fit the body with a glaze having the qualities of a true porcelain glaze, but which will mature at a temperature such that it can be fired below the deformation point of the body.

Previous Research on this Subject.

An investigation as to the effect of composition on the strength of porcelain bodies has been reported by Lester Ogden.[1] A. S. Watts has reported some expansion data secured on European porcelains.[2] R. C. Purdy and A. P. Potts have reported on the coefficients of expansion of white-ware mixtures.[3] E. T. Montgomery and M. G. Babcock have reported an investigation on chemical porcelain[4] and state that this product, which deforms

[1] *Trans. Am. Ceram. Soc.*, **13**, 395 (1911).
[2] *Ibid.*, **13**, 406 (1911).
[3] *Ibid.*, **13**, 431 (1911).
[4] *Ibid.*, **18**, 88 (1916).

at cone 25, must be fired sufficiently high (at about cone 16) to become vitreous and translucent, and that the glaze used must be a hard porcelain one maturing at about the same temperature.

The European low-bisque and high-glost-fire bodies are high in clay, vitrification being secured by high temperature of firing and not by fluxes. Under the microscope these bodies are found to be free from undissolved silica and bonded into a strong mass by sillimanite needles. F. H. Riddle and W. W. McDanel, in reporting an investigation of some types of porcelain,[1] compare European and American pottery practices and the properties of typical and special porcelain bodies. A. V. Bleininger[2] observed that the temperature treatment plays an important rôle in the development of porcelain and that firing temperatures higher than cone 10 are conducive to a more homogeneous structure.

The constitution and microstructure of porcelains have been studied by Zoellner,[3] Plenske,[4] Klein,[5] and Peck.[6] Klein found that in both high-quartz low-feldspar and low-quartz high-feldspar bodies, burned at 1310° C (cone 9), the original clay dissociates into both amorphous and crystalline sillimanite, the former greatly predominating. Quartz is only slightly soluble. At higher temperatures (1380°–1400°) amorphous sillimanite disappears and gives rise to the crystalline form. Quartz, also, dissolves to a considerable extent. Klein concluded that the constitution and microstructure of porcelains depend upon the temperatures of burning and vary with the temperature changes.

The time of burning is a factor of as great importance as that of the burning temperature in determining the constitution and microstructure of the ware. Microscopic examination of porcelains by Peck brought out the effect of time and temperature on the microstructure. Bodies fired for longer periods at lower temperatures were produced which simulated very closely those fired at higher temperatures for shorter periods.

[1] *J. Am. Ceram. Soc.*, **1**, 606 (1918).
[2] *Ibid.*, **1**, 697 (1918).
[3] Sprechsaal, *Yahrgang*, **41**, 471 (1908).
[4] *Ibid.*, **20, 21, 22** (1908).
[5] *Trans. Am. Ceram. Soc.*, **18**, 377 (1916).
[6] *J. Am. Ceram. Soc.*, **2**, 175 (1918).

It must be borne in mind, however, that in commercial practice the fuel consumed in maintaining a low temperature for a long period of time would exceed that consumed in raising the temperature sufficiently high to develop the microstructure of the porcelain in a shorter period. Hence, from an economic standpoint, high-temperature treatment should be resorted to for the production of true porcelains.

Investigation.

The present investigation covers twenty-nine porcelain bodies having the following limits of composition:

Feldspar	10–20 per cent
Flint	30–45 per cent
Clay	30–45 per cent
Ball clay	10 per cent

The range of composition of the mixtures is shown in the triaxial diagram (Fig. 1). It will be noted that the field includes

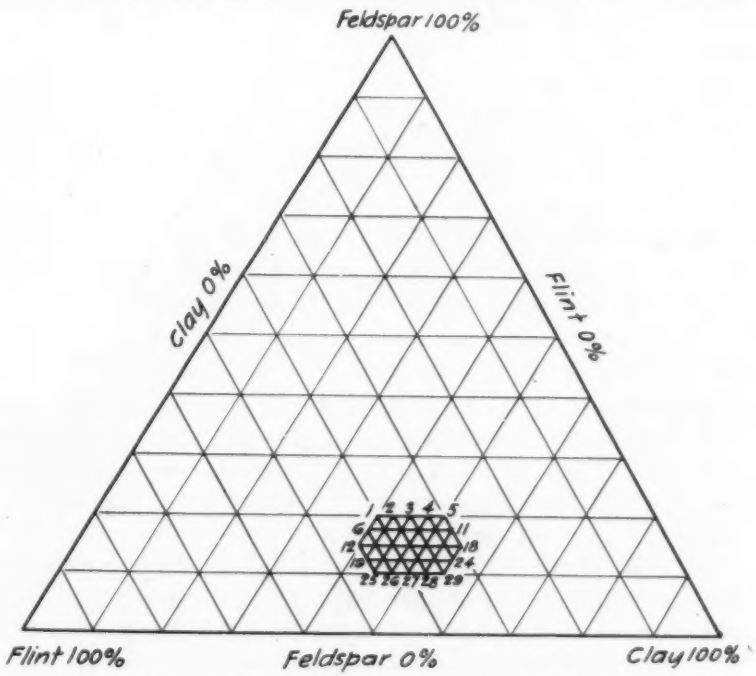


FIG. 1.—Field of body compositions covered.

ordinary white-ware and chemical-porcelain bodies. The chief purpose of this study was to determine the common physical properties of these bodies when fired to cone 10 and cone 13–14.

Raw Materials.—The non-plastic materials used in the bodies were Canadian feldspar and Ohio Silica Co. flint. The clay used consisted of a mixture of 10 per cent Mayfield ball clay and equal portions of McIntyre, Georgia kaolin and Edgar, Florida kaolin. The chemical compositions of these materials are given in Table 1.

TABLE 1.

	Canadian feldspar.	Ohio Silica Co. flint.	McIntyre, Georgia kaolin.	Edgar, Florida kaolin.	Mayfield, Kentucky ball clay.
SiO_2	64.00	99.18	44.90	45.67	61.23
Al_2O_3	19.61	trace	38.49	38.45	25.05
Fe_2O_3	0.43	0.26	0.76	0.75	1.30
TiO_2	...	trace	1.20	0.10	1.35
CaO	0.76	trace	...	...	0.10
MgO	...	trace	...	0.05	0.20
Na_2O	2.46	...			
K_2O	12.78	...	0.30	0.06	1.90
Ignition	...	0.11	...	...	8.35
Total H_2O	...	...	14.35	14.86	...
Combined H_2O	...	...	13.55	13.36	...

Preparation.—Five kilograms of each body mixture was ground in a ball mill for five hours with sufficient water to produce a slip suitable for casting. This slip was passed through a 150-mesh sieve and allowed to stiffen on a plaster slab to a plastic mass suitable for molding and jiggering.

Test Pieces.—Trials in the form of bars, cups, wedges and cubes were made. For each body mixture, eight bars 7″ long and having a 1″ square cross-section (all measurements of trials were made in the plastic state), were made in a brass mold. A shrinkage mark 10 cm. long was scratched on each bar. Ten cups, approximately $2\frac{1}{2}$″ in diameter by $2\frac{1}{2}$″ high, were made by casting and ten, approximately $3\frac{1}{2}$″ in diameter by 2″ high, were formed on the jigger. The wedges, made by pressing in a plaster mold, were 3″ long, 1″ wide, and tapered from $\frac{3}{4}$″ to 0″.

The cubes measured 1" on each side—the corners having been well rounded off by hand.

Drying and Burning.—The trials were first dried at room temperature and finally in a gas-dryer. The cups were finished with a sponge.

Three trials of each shape were fired to cone 10 in a down-draft laboratory kiln. Of these, one cup made of each body mixture was glazed with a porcelain glaze maturing at the same temperature as the body so that a color comparison of the finished ware could be obtained. The other trials were unglazed. A

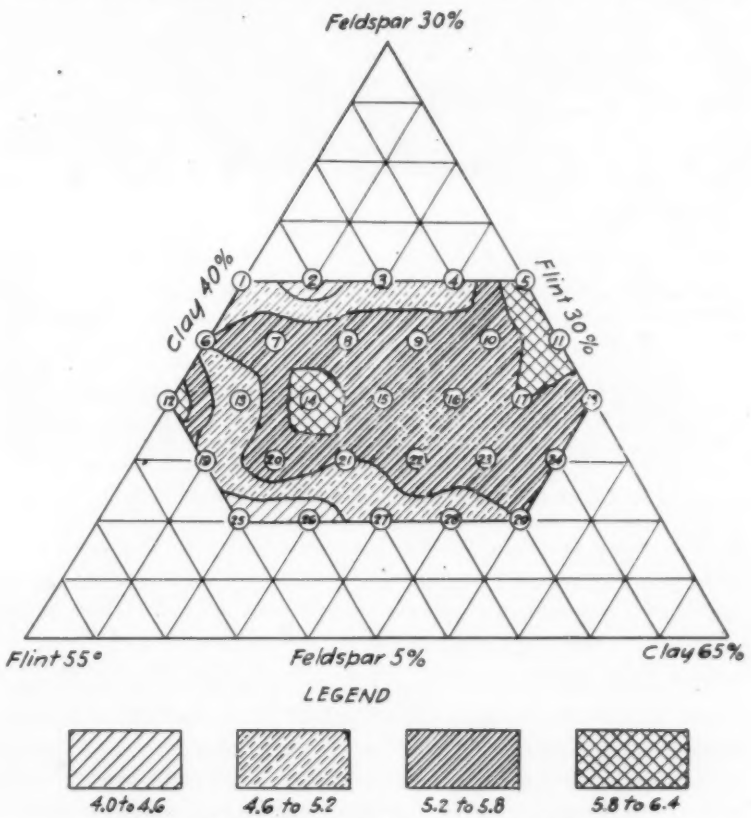


FIG. 2.—Drying shrinkage in per cent of wet length.

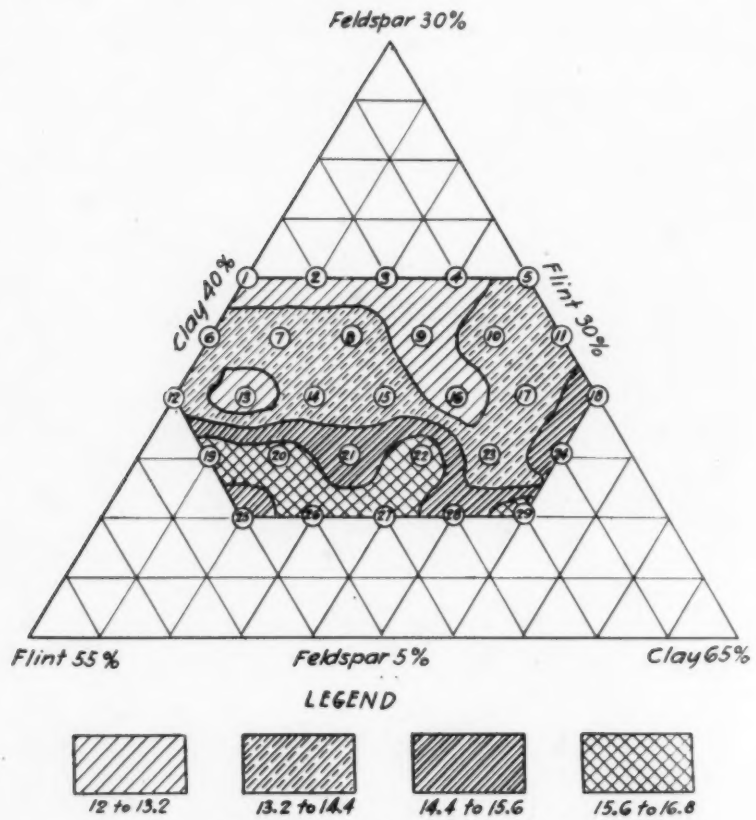


FIG. 3.—Total shrinkage in per cent of wet length.

similar group of trials was fired at cone 13–14 in the same kiln. Cone 10 was reached in twenty-eight hours and cone 13–14 in thirty-two hours, the temperature gradient near the completion of the burn being approximately 20° C per hour.

Shrinkage Measurements.—The drying and burning shrinkages of the bars were measured and expressed in per cent of the lengths of the wet pieces (see Figs. 2 and 3 and Table 2). The burned bars were broken in a transverse-strength machine having knife edges five inches apart. Both the average and maximum moduli of rupture are given in Table 3 for comparison. The maximum

TABLE 2.

Body No.	Percentage composition.			Per cent drying shrinkage.	Per cent total shrinkage.		Per cent absorption.	
	Feldspar.	Clay.	Flint.		Cone 10.	Cone 13–14.	Cone 10.	Cone 13–14.
1....	20.0	40.0	40.0	4.8	13.1	12.7	3.45	0.0
2....	20.0	42.5	37.5	4.6	12.4	12.3	2.72	0.0
3....	20.0	45.0	35.0	5.1	14.6	12.7	2.36	0.0
4....	20.0	47.5	32.5	5.0	13.2	12.5	3.08	0.0
5....	20.0	50.0	30.0	5.9	15.4	14.0	3.64	0.0
6....	17.5	40.0	42.5	5.2	12.7	14.3	4.64	0.0
7....	17.5	42.5	40.0	5.3	13.2	14.0	5.03	0.0
8....	17.5	45.0	37.5	5.4	13.0	13.3	5.34	0.0
9....	17.5	47.5	35.0	5.5	14.5	12.5	5.34	0.0
10....	17.5	50.0	32.5	5.4	13.6	14.0	5.20	0.0
11....	17.5	52.5	30.0	6.3	13.8	14.0	4.09	0.0
12....	15.0	40.0	45.0	6.2	13.6	13.7	4.44	0.0
13....	15.0	42.5	42.5	4.9	12.1	12.3	4.63	0.0
14....	15.0	45.0	40.0	6.2	13.7	14.3	7.52	0.0
15....	15.0	47.5	37.5	5.7	13.0	13.5	5.45	0.0
16....	15.0	50.0	35.0	5.4	14.3	13.0	6.82*	0.0
17....	15.0	52.5	32.5	5.8	15.0	14.3	1.40*	0.0
18....	15.0	55.0	30.0	5.5	15.7	15.3	4.19*	0.0
19....	12.5	42.5	45.0	5.0	14.3	15.8	4.93*	0.40
20....	12.5	45.0	42.5	5.25	14.0	16.0	4.78*	0.57
21....	12.5	47.5	40.0	5.2	13.2	15.5	3.61*	0.0
22....	12.5	50.0	37.5	5.4	13.2	15.7	5.61	0.04
23....	12.5	52.5	35.0	5.3	12.5	14.0	5.27	0.08
24....	12.5	55.0	32.5	5.5	13.2	15.5	5.24*	0.02
25....	10.0	45.0	45.0	4.2	11.8	15.2	9.90*	1.08
26....	10.0	47.5	42.5	4.25	12.5	16.2	9.35*	1.58
27....	10.0	50.0	40.0	5.0	13.2	16.0	9.40*	1.02
28....	10.0	52.5	37.5	4.8	11.5	15.0	7.85	0.82
29....	10.0	55.0	35.0	5.2	13.0	16.5	6.90	0.71

* These figures were interpolated from the actual data obtained as given in Table 4.

moduli of rupture are plotted in Fig. 4. The broken bars were weighed dry and then soaked in water over night. After boiling for one hour, the wet weight of each sample was obtained. From the dry and wet weights of the same sample, percentage absorption

TABLE 3.

Body No.	Modulus of rupture in lbs. per sq. in.				Warpage in inches of deflection. Cone 13–14. 5″ span.	Translucency in mm.		Rattler loss in per cent. Cone 13–14.
	Cone 9–10.		Cone 13–14.			Cone 10.	Cone 13–14.	
	Aver.	Max.	Aver.	Max.				
1....	4737	5900	3347	4200	0.10	2.3	2.8	3.7
2....	6203	6500	6227	6850	0.05	2.5	3.0	5.5
3....	4840	5940	6100	6800	0.0	2.3	2.8	5.0
4....	6820	7350	6957	7460	0.0	2.5	2.8	8.0
5....	4703	5370	7053	8350	0.0	2.5	2.8	9.4
6....	5893	6250	8660	9390	0.09	2.0	2.8	1.40
7....	5743	6030	7940	8210	0.03	2.3	2.7	2.8
8....	4913	5320	8970	10000	0.03	2.0	2.8	3.1
9....	5237	6040	5900	7620	0.05	1.8	2.8	6.0
10....	6373	7350	8917	10220	0.02	2.0	2.5	4.5
11....	5283	5940	7640	8330	0.10	2.0	2.5	4.0
12....	5697	6400	6723	8330	0.10	2.0	2.5	1.7
13....	5607	5800	8233	8420	0.06	2.3	2.8	2.7
14....	4930	5800	9410	10470	0.06	1.8	2.5	2.8
15....	5147	5580	8350	9050	0.08	1.5	2.0	1.6
16....	3700*	4320*	8753	9250	0.07	1.8	2.3	3.6
17....	5200*	5810*	9697	11550	0.05	1.8	2.3	0.0
18....	2500*	2550*	7980	9350	0.08	1.8	2.0	0.2
19....	3030*	3450*	7743	10160	0.0	1.8	2.0	0.0
20....	4300*	4540*	9703	10450	0.06	2.0	2.2	0.4
21....	5590*	5950*	9127	11400	0.0	2.0	2.3	0.4
22....	3890	4300	8670	11280	0.0	1.8	2.0	0.25
23....	2925	3160	11045	11140	0.0	1.8	1.8	0.7
24....	3320*	3860*	9567	10920	0.0	1.7	1.8	1.0
25....	2360*	3200*	6767	7330	0.0	1.4	2.0	0.4
26....	2400*	3100*	7960	8440	0.03	1.5	2.2	0.1
27....	3080*	3760*	7987	9720	0.0	1.4	1.6	0.25
28....	2553	2900	8783	9620	0.0	1.3	1.6	0.4
29....	2960	3600	9707	11200	0.0	1.3	1.6	0.1

* These figures were interpolated from the actual data obtained as given in Table 4.

was calculated on the basis of the dry and wet condition (see Table 2 and Fig. 5). In the cone 13—14-burn, two bars of the same size as above were supported on two clay wedges, having an

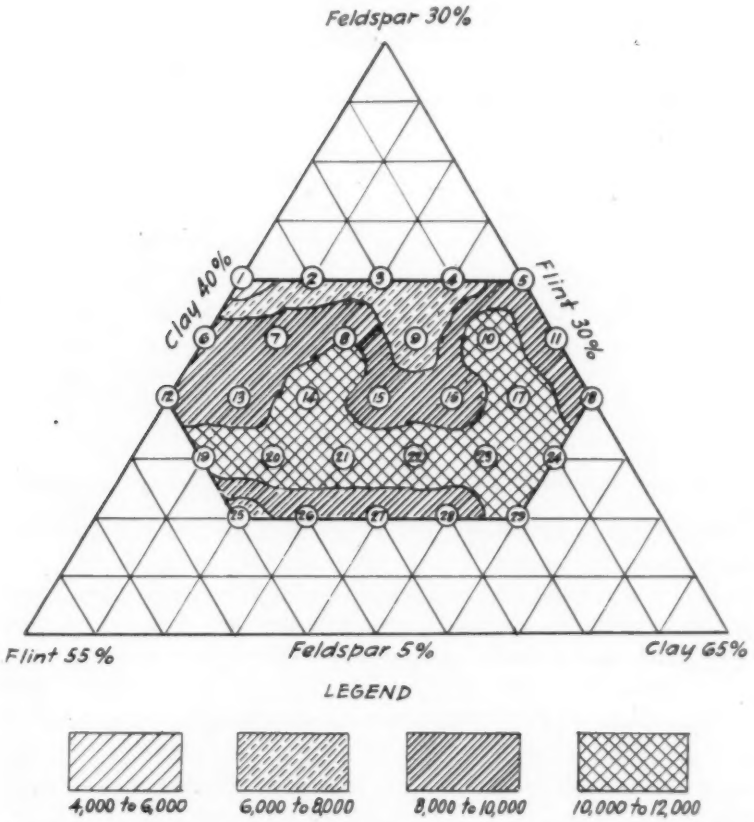


FIG. 4.—Maximum moduli of rupture (cone 13–14) in pounds per square inch.

equilateral triangular cross-section, and placed five inches apart in the sagger. The deflection in inches was gauged as a measure of warpage (see Fig. 6).

Translucency.—For the determination of translucency, the wedges made of different body mixtures were arranged in a row (in good light). A metal wire, about 1 mm. in diameter, was held close to the lighted side of the wedge under examination. The thickness of the wedge, at the point below which the wire became invisible, was measured by means of an Ames dial.

TABLE 4.

Body No.	Firing temperature.	Per cent absorption.	Modulus of rupture.	
			Average.	Maximum.
16.....	Cone 11–12	1.66	3913	4450
17.....	Cone 11–12	0.38	5095	5780
18.....	Cone 11–12	1.14	2185	2820
19.....	Cone 11–12	2.08	3117	3550
20.....	Cone 9	5.79	3750	3960
21.....	Cone 9	4.38	4870	5180
24.....	Cone 9	6.35	3205	3970
25.....	Cone 11	8.02	2460	3360
26.....	Cone 11	7.71	2493	3210
27.....	Cone 11	7.76	3187	3880

The measurements are given in Table 3 and plotted in Fig. 7.

Resistance to Abrasion.—Since an apparatus for the standard rattler test, as specified by the American Society for Testing Materials, was not available, a modified method from which comparative data of the resistance to impact were obtained, was employed. Two cubes of each body composition were weighed and placed in a ten-gallon ball mill (total weight = 1345 gm.). Forty flint pebbles, from $1^1/_2''$ to $2''$ in diameter, weighing 4265 gms., were added and the ball mill run for one hour at thirty-five revolutions per minute. The cubes were then sorted out, dusted, and weighed separately. The loss in weight divided by the original weight gave the percentage rattler loss. The results obtained are tabulated in Table 3 and plotted in Fig. 8.

The study has proven so extensive that a discussion of the glaze will be left to a later date.

Conclusions.

From the data given in the above tables and plotted in the accompanying diagrams, the following conclusions may be drawn:

1. The drying shrinkage and total shrinkage of the bodies studied show great irregularity. Very broadly speaking, however, they increase with a corresponding increase in clay content.

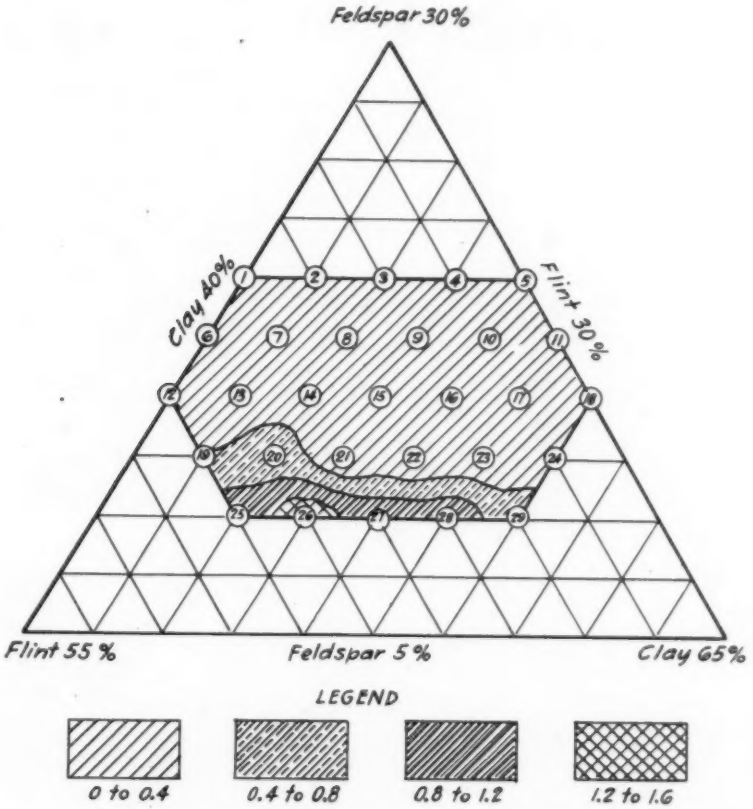


FIG. 5.—Absorption (cone 13–14) in per cent of burned weight.

2. With bodies 1, 2, 3, 4 and 5, which contained 20 per cent feldspar, the total shrinkage was smallerat cone 13–14 than at cone 10. This was due to the development of a vesicular structure in the bodies fired at cone 13–14, as was apparent in the cross-section of the broken bars. The little material increase of cross-breaking strength gained by raising the firing temperature from cone 10 to cone 13–14 points to the fact that these bodies were overburned. Bodies 9, 16, 17 and 18, likewise, did not shrink as much at cone 13–14 as at cone 10. With the small number of trials made, the author is not able to explain the phenomena at present.

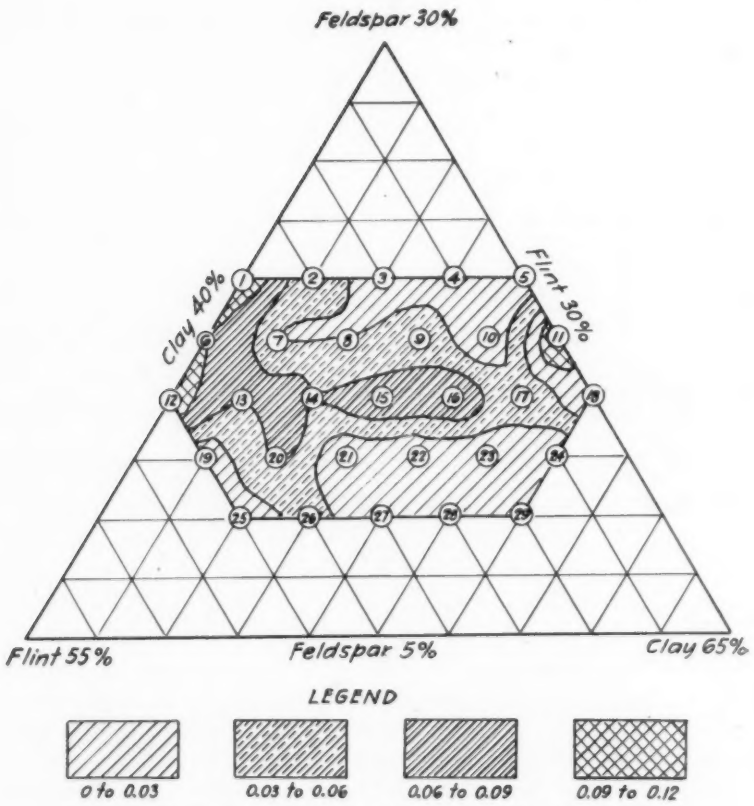


FIG. 6.—Warpage (cone 13–14) in inches of deflection (5″ span).

3. At cone 10 none of the bodies were thoroughly vitrified—as indicated by the considerable amount of water absorbed. All of the bodies containing from 15 to 20 per cent feldspar became non-absorbent at cone 13–14. The bodies containing 12.5 per cent feldspar absorbed a small amount of water, while those containing 10 per cent feldspar absorbed considerably more.

4. A considerable increase in cross-breaking strength was noted in the bodies, other than the first five mentioned above, when fired at cone 13–14. Generally speaking, there was a greater increase in strength in bodies low in feldspar and high in clay, the feldspar being more active.

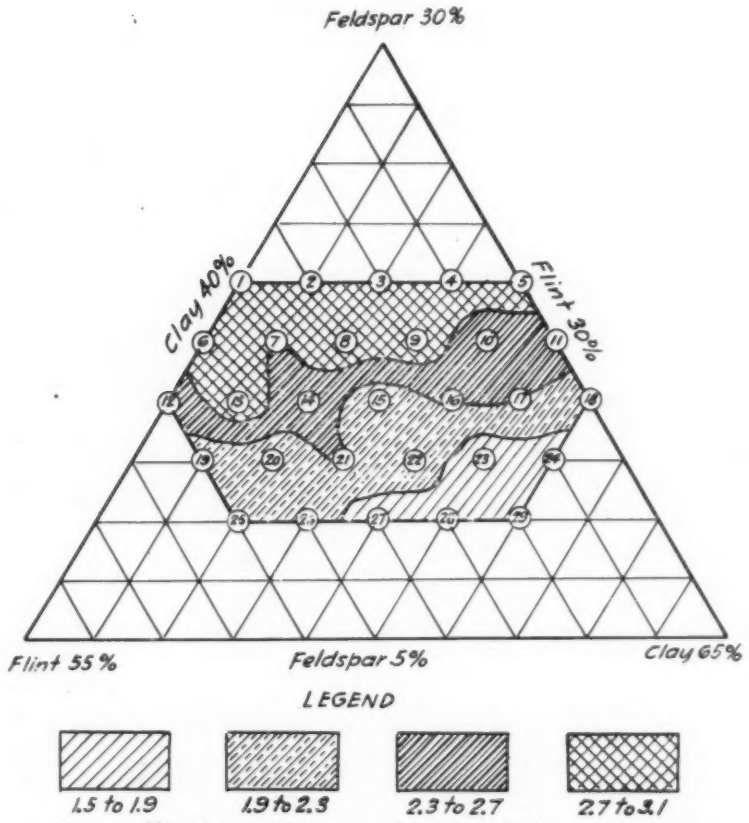


FIG. 7.—Translucency (cone 13–14) in mm. of light penetration.

5. The warpage of the bodies at cone 13–14 showed very irregular variations and, as a whole, was not excessive.

6. The bodies fired at cone 10 were semi-translucent, while those fired at cone 13–14 showed distinct translucency, so far as both depth of light penetration and quality are concerned.

7. The color of the bodies was decidedly improved by firing at a higher temperature. The cone 13–14 product was a beautiful bluish-white, while the cone-10 product appeared creamy. In the bodies fired at cone 13–14, there was a noticeable tendency to a pinkish tinge as the content of feldspar was decreased.

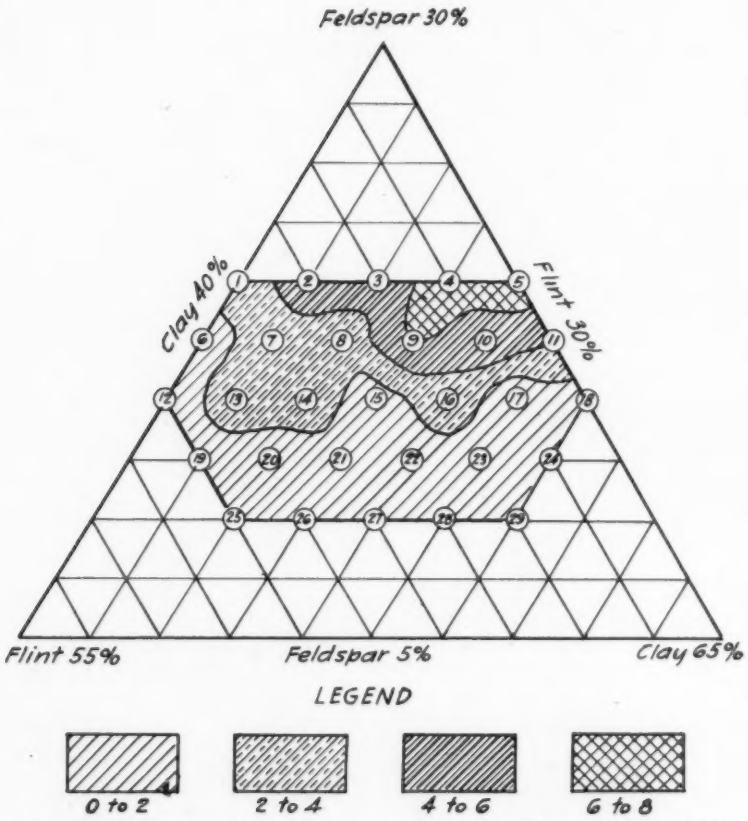


FIG. 8.—Rattler loss (cone 13–14) in per cent of original burned weight.

8. The results of the rattler tests were consistent with the observations of Lester Ogden as given in his paper.[1] Toughness is apparently dependent more on the amount of flint present than on either feldspar or clay. A comparison with the data on moduli of rupture shows that the bodies having high cross-breaking strength, as would be expected, suffered no or little loss in the rattler test.

9. Taking all the above properties into consideration, bodies 8, 17 and 21 were the best of those fired at cone 13–14.

[1] *Trans. Am. Ceram. Soc.*, 13, 395 (1911).

Acknowledgment.

Prof. Arthur S. Watts has given valuable advice during the progress of the investigation. His assistance and encouragement made the work an instructive as well as enjoyable undertaking. To him the author wishes to express his appreciation and acknowledge his obligation.

OHIO STATE UNIVERSITY,
COLUMBUS, OHIO.

THE MANUFACTURE OF ABRASIVE WHEELS.[1]

By S. C. Linbarger.

When civilization reached the stage of advancement where man began to form weapons and the implements necessary for his existence from hard metals instead of stone, he came to realize the distinct advantages which could be gained if it were possible to smooth the surface and sharpen to a keen edge the weapon so crudely fashioned. It was only the natural sequence of events which led to the discovery of a substance supplied abundantly by nature, which when rubbed over the surface of the metal would abrade it and gradually wear it away. Although the abrasive properties which some of these rock formations evinced were greatly inferior to others, they gained widespread use owing to their geologic occurrence and to the suitability of other of their physical properties. The ultimate result was that natural sandstone attained a paramount position in the abrasive field which it held for many years.

Even the introduction and perfecting of the artificial wheels in which grains of natural minerals were used did not materially affect the status of the natural grindstone. However, the latter is now being rapidly superseded, even in the small village blacksmith shops, by grinding wheels made of artificial abrasive material.

This of course only follows in line with a similar replacement which took place in the large metal-working factories several years ago. They were the first to realize the decided advantage to be gained in amount of production and accuracy of finish obtained by using grinding wheels which could be made with physical characteristics applicable to their individual grinding conditions.

The advent of better and more accurately constructed machines having interchangeable parts and the desire to produce them as rapidly and economically as possible, has been an influential factor in the development and the universal adoption of the artificial

[1] Read before the New York State Section of the American Ceramic Society, Syracuse, N. Y., May 9, 1919.

abrasive wheel as a necessary adjunct to present day metal-working equipment. Especially is this true in the automotive industry which demands standardized parts in enormous quantities. The quantity-production of Liberty-motor parts which was reaching such large proportions during the latter days of the World War, to say nothing of truck and tractor production throughout the entire war period, would have been impossible without the artificial grinding wheel and the modern grinding machine. There is not one of the multitude of parts in an automobile but whose production is directly or indirectly influenced by the efficiency of electrically-formed abrasives. And it can be safely stated that without them the price of automobiles today would be prohibitive to all except the very rich, and the number of farm tractors in use could be stated in hundreds instead of thousands.

Nearly a half-century ago the desire for a better grinding medium led the pioneers in the industry to seek some satisfactory means of bonding the hard, sharp particles of emery and corundum into an integral grinding wheel. Owing to the hardness of the grains of the material and the ability to control the coarseness and density of the finished product within certain limits, it rapidly replaced the natural stone in places where its initial cost was not a deciding factor.

When carborundum was discovered several years later, its value as an abrasive was immediately apparent owing to the extreme hardness and sharpness of the solid plate-like crystals unlike any found in nature. However, it was several years before it could be manufactured cheaply enough to warrant its use other than in the polishing of rare gems. When electric furnaces were devised and designed wherein this material could be made in sufficient quantities and at such cost of production that it could be profitably used as an ingredient in commercial-sized grinding wheels, the question of binding the crystals into an integral wheel arose. The adoption of fusible clays as a matrix for securely bonding the crystals was immediately recognized and practical wheel-makers, who had gained experience in the bonding of natural emery, set about to produce wheels composed of bonded silicon-carbide crystals. Their efforts were crowned by the production

of a satisfactory wheel which proved greatly superior to natural abrasives in many grinding operations. At first the production was necessarily limited to this one class of wheel. As its introduction into the machine shops of the country became more universal, the need for wheels which would cut faster and cooler and give greater production on certain classes of work presented complex problems which involved laborious and extended ceramic research.

The ingenuity of the men to whom this work was entrusted soon asserted itself and it was but a short time until the ceramic problems involved in bonding carborundum had reached a high state of perfection. At the outset it was seen that carborundum was not adapted to all classes of grinding, as even the natural abrasives proved more efficient grinding mediums on the hard, high-tensile-strength materials. But owing to the non-uniformity in physical properties and chemical composition of the natural abrasives, great difficulties were encountered in bonding the grains and producing wheels of uniform quality from time to time. This led to the development of an artificial aluminous abrasive which was much superior in cutting properties to natural emery and could be made uniformly from day to day. Combinations of bonding materials which were adaptable to carborundum were not suitable to this new aluminous abrasive. Neither were those which had been used successfully with corundum entirely satisfactory, consequently new processes of manufacture and bonding had to be worked out. As soon as the high efficiency of grinding over turning was demonstrated and the modern grinding machine was introduced, the new and varied uses to which grinding wheels were applied necessitated a scientific study of the desirable qualities which a grinding wheel should possess for certain factory conditions and various classes of work. This research has continued unabated until at the present time the grinding-wheel manufacturers are in a position to furnish wheels of the proper grit and grade and the proper density and toughness of bond to meet the individual grinding conditions of the consumer.

When it is realized that the speed of the wheel, the speed of the work, the type of machine, and the physical properties of the material to be ground affect the rapidity of cut and the life of the

wheel, it is apparent that it is not possible at the present time to produce a universal wheel for grinding a given class of material. For instance, manganese steel as produced by different companies for different purposes might vary as much as ten per cent in the manganese content and have such vastly different physical properties that the type of wheel which would be suitable for the high-manganese steel would be wholly unsuited to grinding the other. Again, one plant might desire to grind the fins and risers from large electric-steel castings. As these sharp promontories exert considerable dressing action, the grinding wheel must be tougher and harder than one used on steel of the same composition but where the castings are light in weight. In the snagging operations, heat generated in the grinding operation is of little or no consequence, while in the case of finish grinding, cutting without the generation of heat is the chief desideratum. Therefore, wheels of different density and bond structure must be supplied to successfully meet the conditions encountered.

These are only a few of the innumerable instances that could be cited wherein the abrasive-wheel manufacturer is compelled to produce a product that will meet the demands of the customer and he must further be able to duplicate the wheels which are supplied on succeeding shipments. This duplication resolves itself into maintaining a uniform strength of bonding material, the same hardness or grade of wheel, and simultaneously keeping a uniform density of wheel structure.

The bonding of abrasive wheels can be grouped under three general classes, depending upon the bonding material used, namely: vitrified, silicate and elastic. In the case of vitrified bonds, the binder consists of a clay or clays which fuse at commercial kiln temperatures. In the silicate type of wheel, the bonding matrix is principally sodium silicate or commercial water-glass combined with chemical substances which produce an insoluble silicate at low temperatures. The organic binders may be any insoluble organic compounds but the principal ones now used are shellac and rubber.

Artificial abrasives are manufactured at temperatures only obtainable in electric furnaces. In the case of carborundum the crystalline material is formed by passing an electric current

through a mixture of sand, sawdust and coke which is packed in a long, rectangular resistance-furnace. By the utilization of an enormous amount of electrical energy, the temperature of the furnace is brought up to the temperature at which the silica is volatilized. In this gaseous state one molecule of carbon combines with an equivalent amount of silicon, forming upon cooling a core of pure crystallized carbide of silicon between the electrodes, which are located in opposite ends of the furnace. As this material is a definite chemical compound, the crystals always have the same physical properties.

Aluminous abrasives are formed by the conversion of an amorphous aluminous substance into a crystalline aggregate of alumina crystals cemented together by a matrix of refractory oxides. This change is brought about by the fusion of the crude material, which occurs in nature as the mineral bauxite, in an electric furnace of the arc type. By the exercise of accurate chemical and electrical control during the furnacing process, it is possible to produce aluminous abrasive-grains of various degrees of hardness and toughness which make them peculiarly applicable to certain classes of grinding operations.

After cooling, the furnaces and pigs are carefully stripped of all unconverted or unfused mix and the suitable material is crushed to a size convenient for transportation to the grinding-wheel factory. The lumps are then crushed in powerful jaw crushers and further reduced in successive rolls which gives a range of sizes which are suitable for use in abrasive wheels, sharpening stones, refractories, etc. Dust, dirt and other foreign material, which may have been introduced in the handling and crushing of the crude material, is removed by thoroughly washing the grains by hydraulic means. It then passes through a dryer which removes all traces of moisture. Particles of iron and other magnetic contaminations are removed by passing the material over a magnetic machine. The grains are then accurately graded by passing them over screens of the proper mesh. The range of grits used is from those which will pass an 8-mesh screen to those of almost impalpable powder. The fine powders which cannot be accurately graded by screens or cloths are separated by hydraulic classifiers

which are similar in construction to the elutriators as used in determining the fineness of grain of clays.

Vitrified wheels are made by two general processes known respectively as the pressed and puddled process. In the pressed process the procedure is to weigh out a given amount of the desired abrasive grains of the proper gradings and to this is added a certain percentage of the bonding ingredients. The amount and character of the various clays used depend, of course, on the desired physical properties which it is wished to impart to the finished wheel. The components are then thoroughly mixed in a dry condition in a mechanical mixing device after which enough water is added to make the mass adhere. The consistency obtained is about like that used in a dry-pressed brick. The material is evenly distributed in a mold which is of slightly larger dimensions than the size of the desired finished wheel or stone. The mold is then placed in a hydraulic press and subjected to a high pressure. The amount of pressure applied depends upon what characteristics and grades are to be developed in the ultimate product. The green wheels next go into a drying chamber or dry house where they are dried very slowly. They remain here until they are thoroughly dry and in a proper condition to be handled and set in the kilns.

Upon delivery to the kiln room, each wheel or abrasive stone is carefully inspected for molding- or drying-cracks and only those which show no defects are allowed to go into the kilns.

In the puddled process, the accurately weighed grain and bond are placed in large mixing kettles and a sufficient quantity of water is added to bring the mix to a thin slip condition. When the ingredients are thoroughly mixed, the slip is drawn off into molds which are somewhat larger than the desired wheels. The puddled wheels, as they are designated, are placed in dry houses until they become sufficiently dry to handle. They are then removed from the molds and go to machines where they are cut to within a fraction of an inch of the proper diameter, thickness, and arbor hole; the additional stock being allowed for final finishing and trueing after coming from the kilns.

From this point on the two processes converge and the method

of completing the finished products is the same as that employed in the manufacture of pressed wheels.

The kilns used are the ordinary type of pottery kiln and the ware is placed in saggers and set in stacks or bungs in a manner similar to that employed in the burning of the more delicate ceramic wares. The kilns are fired to a temperature sufficiently high to thoroughly vitrify or flow the bonding materials. Coal is the fuel used and, owing to the high temperatures required to mature the bond and to the large mass of material which must be uniformly heated to this temperature, the length of time required for a complete cycle of the kiln is about two weeks.

As the name implies, the bond ingredient of vulcanized wheels is rubber. The process employed in the manufacture of this type of wheel is similar to that which is used in the fabrication of all rubber products. The proper proportions of abrasive grits and high-grade crude rubber are weighed out and enough sulphur to insure proper vulcanization is added. The ingredients are then mixed by repeatedly passing the mass through steam-heated rolls. After a homogeneous mixture is obtained, the material is passed through finishing rolls which are spaced so that the material issues from the opposite side in a sheet which is the thickness of the desired wheel. The slabs are then cut into discs of the correct diameters and having the proper sized arbor holes. The green wheels are then given a careful heat treatment to insure proper vulcanization of the bond.

Silicate and shellac-bonded wheels are formed by intimately mixing the respective ingredients with grain and forming in molds by the application of pressure. They are baked in ovens at low temperatures, the degree of heat being just sufficient to impart the requisite strength or bonding properties to the bond.

The wheels go from the kilns and ovens to the finishing department, where the crust or scale developed in the burning process is removed from the sides or face of the wheel and it is brought down to the proper thickness and shape desired. This is accomplished by passing a hardened steel dresser or a diamond across the flat face of the wheel while it revolves in a lathe-chuck.

The wheels are again inspected very rigidly for uniformity of mix, proper fusion of bond, and defects due to burning and hand-

ling. They are also carefully tested at this time for proper grade. *Grade* is a term used by abrasive manufacturers to designate the relative hardness of an abrasive product. It is usually designated by a letter or number, the most common method being to use the letters of the alphabet. Some companies use the first letters to distinguish the harder grades while others use just the reverse. Grade is often erroneously looked upon as an absolute value. Although every precaution is taken by the manufacturer to maintain a strict technical control over every ingredient and step in the process which enter into the manufacture of his product, it is impossible to do more than establish certain limits within which the hardness of a wheel must fall to be of a given grade.

The grade of a wheel is determined by the resistance which it offers to the penetration of a small chisel-shaped tool which oscillates about its longitudinal axis through an arc of about 90 degrees. In order to maintain a uniform product and to keep within the prescribed limits, reference and comparison are frequently made with a set of standard grade-pieces which are kept for that express purpose. If a wheel proves to be of a harder or softer grade than the markings on it would indicate for which it was made, it is rejected by the inspector and scrapped. If it is satisfactory in all respects, it proceeds to the bushing department where a lead-, or in some cases, steel- or babbitt-bushing is put in the wheel, with a hole or arbor left in it which is a few thousandths of an inch larger in diameter than the spindle on which the wheel is to be operated.

The next operation is to bring the wheel down to the proper diameter. This is done by revolving it on a spindle and passing a diamond or wheel-dresser across the peripheral face. The finished wheel proceeds to the balancing ways where it is tested for absolute balance. A wheel out of balance would cause endless trouble in most grinding operations, with a consequence that wheels must be in perfect balance when they leave the factory.

In order to determine conclusively that the bond has sufficient tensile strength to withstand the centrifugal forces set up when the wheel is in operation and that there are no invisible defects in the structure, the wheels are next given a speed test. This consists in rotating the wheels on a spindle which is connected with

a main driving-shaft by means of cone pulleys so that any desired speed can be obtained. The wheel is encased in a steel lined compartment so that in case breakage should occur, the pieces are confined. The recommended speed for vitrified wheels is from 5000 to 6000 surface feet per minute. In order to insure complete safety in operation the wheels are speeded to approximately fifty per cent above the recommended operating speed. The order number and test number, with the speed at which the wheel has been tested, are recorded and the workman who speeded the wheel is required to go before a Notary and swear to the truthfulness of the speeds which he has recorded.

The wheels after leaving the speeder are again carefully inspected for defects in workmanship and go to the expert graders who pass on the hardness or grade. All satisfactory material goes to the shipping room where it is packed carefully in sawdust, to prevent breakage in transit, and is then ready to go to the ultimate consumer.

When it is realized that abrasive wheels must be made in all sizes from the very minute points which are used by dentists to wheels 36″ in diameter and 12″ thick, and meet all the conditions encountered in grinding practically everything from feathers to the hardest alloy steels, and give desired finishes on work which will embrace everything from snagging castings to putting an edge on razor blades, one can readily understand the innumerable classes of materials which the grinding-wheel manufacturer is compelled to produce and duplicate from time to time.

Carborundum Co.,
Niagara Falls, N. Y.

THE EQUIPMENT OF A CASTING PLANT FOR THE MANUFACTURE OF GLASS POTS.[1]

By Frank H. Riddle.

During the past two years the Clay Products Section of the Bureau of Standards has developed methods for the manufacture of glass pots by the casting process. The object of the present paper is to describe the methods used and proposed plans for a plant suitable for casting ten 600-pound glass pots per day.

The general plan for such a plant is shown in Fig. 1. The different units are so arranged that the materials and products move continuously forward through the factory and there is no interference between the various processes and units.

Storage and Preparation of Pot Materials.

The first unit is that used for the storage and preparation of pot materials and is shown in the upper left portion of Fig. 1. Along the outer wall of the room, facing the railroad siding, are the storage bins for raw, unground materials. The capacities of these bins will depend upon the composition of the pot body. About half the total capacity will be used for grogs and the remainder for ball clays, kaolins, feldspar, etc.

The equipment for this unit consists of a bench A, for cleaning pot shell, jaw crusher B, dry pan C, elevator screen and return chute D, magnetic separator M, elevator E and dump car F running on the track G over the ground-material storage bins. The raw materials are transferred from the storage bins by wheelbarrow or conveyor to the crusher or to the dry pan. All material that passes through the dry pan is passed over the screen D. The properly-sized materials may be passed over the magnetic separator M or sent directly to the elevator E which unloads into the dump car. The tailings are returned directly to the pan to be more finely ground. If the grog is to be sized it is necessary,

[1] By permission of the Director, Bureau of Standards.

of course, to use several screens in a set; separating the various sizes after they pass through the screens. Experience has shown that the grog should be accurately sized and also be passed over the magnetic separator. Magnetic separators for dry-ground materials are now on the market and although the first cost is high the better quality of the product warrants the investment.

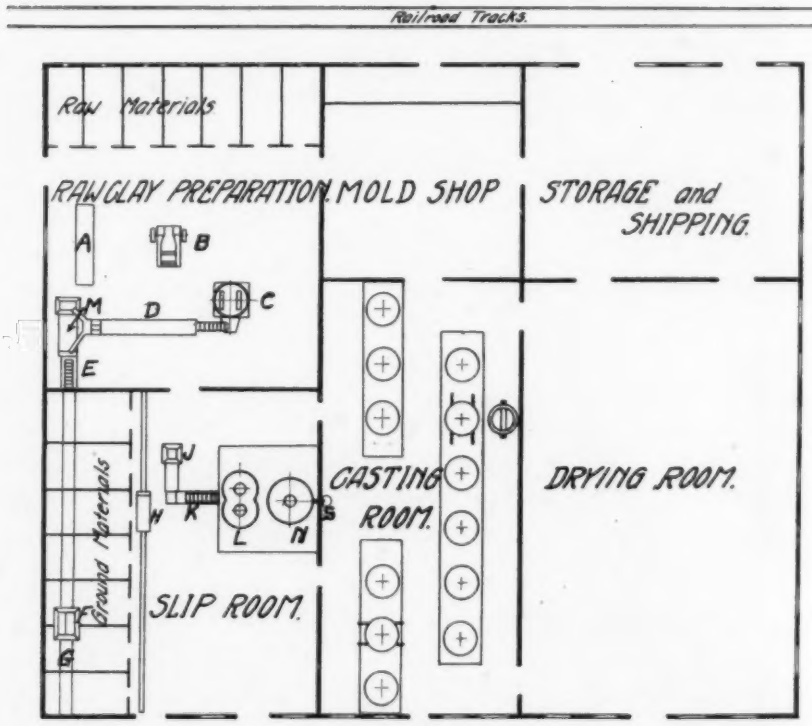


FIG. 1.

Preparation of the Casting Slip.

The next unit of the factory is the slip-preparation room. The ground materials are shoveled from the bins into a scale car H (Fig. 1) which runs on a track as indicated. The size of this car will depend upon the size of the blunger. Regardless of the size of the car, all of the materials should be added in the proper

proportions to make the batch weight used. The materials are transferred from the scale car to a dry mixer J, from which they are discharged into the boot of the blunger-charging elevator K. A continuous mixer should be used. The mixed materials are raised into the blunger L. It is desirable that the blunger be located at a height sufficient to allow the slip to flow by gravity into an agitator, N, then over a 4-mesh screen four feet above the floor of the casting room.

The blunger may be of either the single- or double-paddle type, but the latter is preferable. Both vertical shafts should revolve in the same direction to give the best results. If a single blunger type is used, the lining should be shaped so as to form a hexagonal interior rather than cylindrical, as this tends to prevent the mass of thick slip from rotating as a unit. In a double blunger the lining should extend from the center of each side into the space not swept by the shaft arms—thus preventing the slip from accumulating at these points. The surface of the lining should be made as smooth as possible to facilitate cleaning.

The body should be blunged at least three hours. Somewhat longer than this is preferable; in fact, it is better to use a blunger large enough to contain sufficient slip for an entire day's run. A blunger with a slip capacity of 680 gallons will hold sufficient slip for casting ten 570-pound pots. It should have a slightly larger capacity, however, to allow for loss.

If the blunger is of sufficient capacity the agitator may be dispensed with. The blunger, and agitator if used, should be covered to keep the slip clean and to prevent excessive evaporation of water. Large ports and open troughs should be used for emptying out and transporting slip so that they can be cleaned easily. The discharge pipe or trough from the slip room into the casting room should be placed at a height such as to permit easy operation by a man standing on the casting-room floor. Time is thus saved in filling the carrier bucket. The feed troughs and agitator should be thoroughly washed whenever necessary and a settling tank be provided to catch any grog in the wash water so as to prevent it from clogging the factory drain system.

A body of the following composition has proven satisfactory for optical-glass pots, both from the view-point of the casting be-

havior of the slip, and that of burning the pots and melting the glass:

Material.	Per cent.
Whiteware bisque grog	48
Ball clays	18
Kaolins	28
Feldspar	6
	100

The specific gravity of the slip is maintained at about 1.90. The salts added amount to 0.2 per cent of the total weight of the dry materials. For this particular body, equal amounts of sodium silicate and sodium carbonate are used.

The method of charging the blunger is as follows: The required amount of water is first introduced and the sodium silicate added. The body materials are then introduced, although only about one-half the total batch is charged at first, and allowed to blunge for a few moments until well mixed. The amount of each successive addition of body material is less than the previous addition. The length of time required for each charge to become thoroughly mixed with slip will, of course, increase as more material is added and the mixture thickens. The entire time of charging is about one hour. When this is completed, the sodium carbonate solution is added and the blunging continued. The consistency of the slip should be carefully determined from time to time. This may be judged by feel and by the weight per pint, or by means of a flow-viscosimeter. The latter should have a capacity of at least one gallon and an efflux not less than $^3/_4$ inch in diameter.

The Mold Shop.

Before going to the casting unit the mold shop will be described at this point. As shown in Fig. 1, the mold shop is located at the end of the casting room so that the casting-room bridge-crane can be used both in making and distributing the molds. The mold shop should be at least as wide as the crane-way and not less than fifteen or twenty feet long. A longer room will permit of the storing of blocks, cases, spare molds, plaster, etc.

The mold can be made by actual turning on a horizontal wheel, similar to the surface grinder used for grinding sanitary ware. The diameter of the wheel must be as great as the diameter of the pot mold. Provision should be made for mixing sufficient plaster to make an entire mold-section at one pouring. The grinding wheel may be omitted if the molds are built on a flat-top table with sweeps, as is the practice in the making of terra-cotta molds.

The shape of the mold is very important and the design should be carefully worked out. The size of the belt, slope at the under edge, and other details should be accurately determined.

The mold consists of four parts, as shown in Fig. 2; namely, base, shell or case, ring, and core. The shell must be tapered to allow lowering away from the pot and base which are supported on the pedestal. The core must taper sufficiently to permit lifting up from the cast pot through the ring. The shell and ring should both be well bound with steel bands. The mold rests on a wooden frame which is long enough to span the floor trench and wide enough to allow clearance between the two side members of the frame for it to fit down over the pedestal. However, the clearance should not be greater than necessary, since the base piece of the mold must rest on the frame and the two cross pieces which hold the frame together. The core is clamped down into the shell and ring by means of a cross plank which is bolted on both ends to the support frame (see Fig. 2). A funnel with three openings leading down through the ring into the mold should be provided. The leads should be spaced at equal distances and be two or more inches in diameter. All metallic parts through which the slip flows should be made of galvanized iron.

When the experimental work in the casting of glass pots was first started it was thought necessary, for the continuous operation of a casting plant, to have duplicate sets of molds so that one set could be used one day and the duplicate set the next day while the first set was drying. A year's experience, however, has definitely proven that it is possible to use the same set of molds continuously through the week, allowing them to dry out over Sunday. This saving in molds, space and equipment is of considerable importance from an operating standpoint. To facilitate this daily operation it is advisable to have the walls of the molds

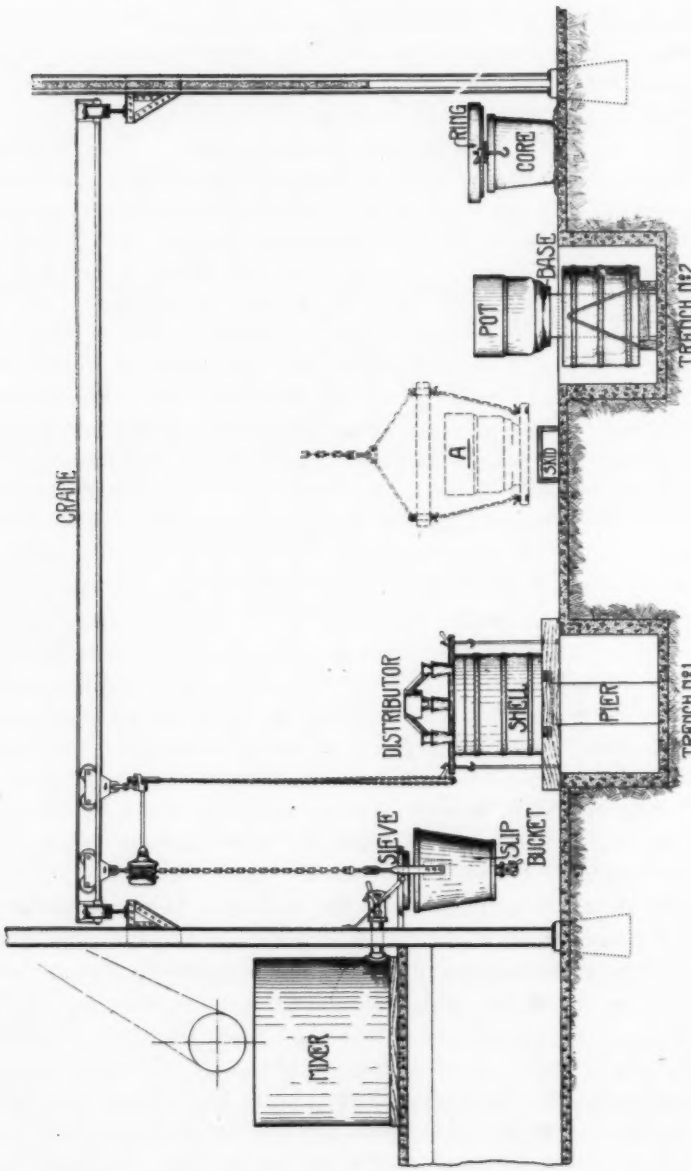

RING
CORE
BASE
POT
TRENCH N°2
A
SAND
CRANE
DISTRIBUTOR
SHELL
PIER
TRENCH N°1
SIEVE
SLIP
BUCKET
MIXER

FIG. 2.

as thin as possible without detriment to their strength. Also, to maintain the temperature of the casting room at from 60° to 70° F during the day time and from 70° to 80° F at night, at the same time keeping the air well circulated. If these conditions are maintained the water absorbed from the slip by the mold is evaporated from the surface of the mold as rapidly as it collects and the work can go on continuously. If the room is cold and damp and the walls of the molds too thick, it will be necessary, after the molds have become saturated, to stop work until they can again be dried out. These precautions also apply to the casting of any kinds of ware in plaster-of-paris molds. The strength of a thin mold can, of course, be very much increased by the use of bands or other outside supports. Reinforcements may also be used in the mold but the former methods are preferable.

Casting.

The casting room is arranged (see Figs. 1 and 2) with a traveling bridge-crane covering the entire area of the room. The crane should not be heavier than necessary and a one-ton chain block is sufficiently strong. The ease of working could be facilitated by having the room six or eight feet wider, by placing a row of posts down the center and by using two cranes, each covering half the width of the room. This would necessitate a trough for carrying the slip to the far crane but this could be accomplished. The crane is arranged with slings; one for picking up the entire mold; one for picking up the pot; and one for carrying the slip bucket.

The floor space is arranged so that the molds are set up in two longitudinal rows. There is sufficient space between the side walls and the line of molds to permit the placing of the cores and rings on the floor when removed from the molds after casting and enough additional space to permit handling the case. An aisle is left between the two lines of molds wide enough to allow space for handling the pots and trucking them away. Space should be provided at each end of the room to permit passage of the pots into the dryer room at the side. There should be a break in the center of the line of molds, on the side near the agi-

tators, so as to allow the slip-carrying bucket to be run in under the slip spouts (See Fig. 1).

As shown in Fig. 2, there is a depressed floor or trench under each line of molds. This is deep enough to permit lowering the case mold and its carriage so that the top is below floor level. A series of piers or pedestals is built along the center line of each depression and spaced longitudinally so that their centers coincide with the centers of the casting molds when in position. These pedestals are of a height such that they project above the floor level about 4″ less than the height of the mold-support timbers.

The operation of filling the molds is simple. The slip bucket, supplied with an outlet beneath, is placed under the agitator-tank outlet and filled with slip (it is best to pass the slip through a coarse screen). The filled bucket is lifted and carried by the crane to a proper filling position over the mold. The filling should be continuous to prevent the trapping of air. The air outlets or issue holes, cut in the core where it fits into the ring, should be large enough to permit the slip to flow as rapidly as possible from the tank. The entire operation of filling should not require more than 10 minutes.

The filling should all be done through one port and the slip not allowed to flow into the other ports until the mold is full. Several casts were made with the slip flowing down the three ports at the same time and joining at the center in the bottom. In this case the areas of contact of the slip coming from each port failed to join thoroughly and defects resulted. Fig. 3 shows two sides of one of these weak unions—sufficiently weak to permit the glass to eat entirely through (note the flow lines of slip in the body).

When sufficient slip is poured in to run well up toward the top of the funnel, there will be enough to complete the casting, allowing for the settle of the slip due to absorption. The height of the funnel above the mold and the resulting pressure affect the casting. This height of supply and the pressure produced are very important points and the life of a pot is largely determined by the pressure used.

The length of time of casting is governed by the kind of slip and the dryness of the mold. It will probably vary from 16 to 24 hours. With a 16- to 18-hour cast, the system works very well

as the molds can be filled the latter part of the afternoon and emptied the next morning.

The mold has an air-inlet plug in the center of the bottom of the core. This can be reached from the top and the hardness of the cast can be determined by removing the plug and feeling the clay body. The thickest part of the pot and the last to cast solid is at this point.

To remove the pot from the mold, the funnel and leads are first taken off. By unscrewing the two lever nuts and unhooking

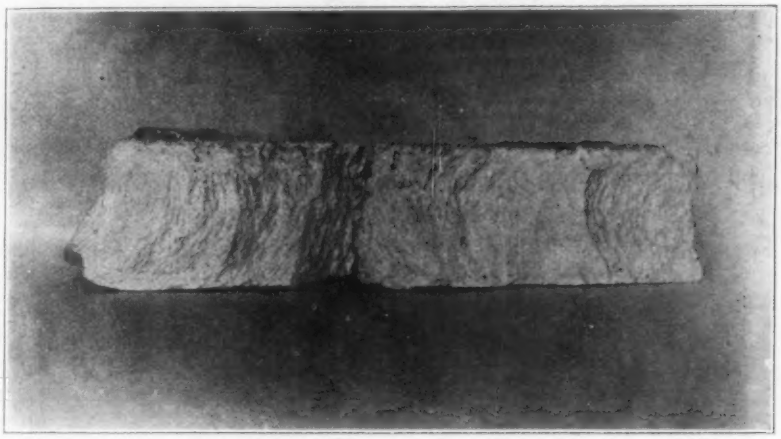


FIG. 3.

the bolts the plank that holds the core is then removed. The core is then lifted out by the crane. This may bind somewhat to the ring or the pot may have shrunk around it but it should release without using force. If the pot has remained in the mold too long it will shrink around the core so tightly as to cause splitting.

The core is placed on the floor directly back of the rest of the mold. It should be placed on a pad of some sort to prevent scratching. The tie board is placed across the top of the core and the ring is lifted by hand off the case and put on top of the board. This leaves the inside and top of the pot exposed. If the pot

is too soft to stand alone, the shell should be left so as to support the pot until stiff. If the core is drawn about 9 A.M., as it should be, the pot will be stiff enough to move at 2 P.M. Sometimes it may be removed at once.

When the pot is of proper stiffness the crane is hooked on to the mold frame-support and the whole arrangement lifted; including frame, shell, bottom and pot. When the bottom of the frame clears the top of the pedestal the frame is turned 90° and the load gradually lowered. When the bottom rests on the pedestal it will release from the shell as the shell continues to lower and the bottom and pot will be left on the pedestal and the frame and shell lowered into the bottom of the trench. The trench can then be covered over with planks, if desired.

To remove the pot from the pedestal a special sling is used as shown on the drawing. This consists of two timbers arranged on collapsing hold-rods which can be put under the plaster bottom, one on each side of the pedestal. By having these rods so that the two timbers can be spread, they can be lowered down over the pot and base while spread. They are then folded in snugly to the sides of the pedestal beneath the base. When the sling is placed, the pot is picked up and lifted over to the runway between the two lines of molds and lowered down on to a suitable skid board for use with a lifting truck or transveyor. The width of the platform must not be any greater than the width of the pedestal and its length must be great enough so that the inside distance between the two skids allows clearance for the truck to be slid under the platform.

In setting the pot and bottom down on the platform, the platform should be placed with the narrow-way crossways to the aisle so that the truck when slid under will be in position to be pulled away without any turning.

The pot is left on the plaster base until stiff enough to move. There should be enough extra mold bottoms provided to meet whatever requirements there are.

In fitting the mold together again for a new cast a dry bottom should be placed on the pedestal and the shell lifted around it.

It is not considered necessary to discuss drying and storage.

There are several modern sytems which may be successfully employed.

Figs. 4 and 5 show a split mold and a pot cast in same. These illustrations show what is actually being done with hooded pots

FIG. 4.

FIG. 5.

of the regular glass-house type. The hood and bottom are cast in one piece up to the line shown in Fig. 5. The top of the hood and cover are cast in a separate piece. When properly stiffened, the top is turned over and stuck on to the bottom. The casting of the two parts separately is necessary on account of the use of the core. Molds for pots of this type can be arranged to work with a shell and inside bottom to the mold, as shown in Fig. 2.

Summary.

Sufficient casting work has been done to demonstrate that this process can be adapted to a great many products as well as glass pots, and that its use is worthy of consideration.

Experiments are being made commercially with pots similar to the one illustrated in Fig. 5. It may be interesting to note that one of these pots has been in use with lime-soda glass for a period of 16 weeks and has already been charged 96 times. The body used is of the type given above.

In conclusion the writer desires to say that the methods described have been developed through coöperation between the Clay Products and the Glass Sections of the Bureau of Standards.

Bureau of Standards,
Pittsburgh, Pa.

NOTE ON THE CASTING OF PORCELAIN GLASS POTS.[1]

By J. W. Wright and D. H. Fuller.

The procedure of casting glass pots has been described by several contributors to This Journal.[2] It is the purpose of the present paper to call attention to several points of practical importance.

The characteristics of a casting slip as well as of the fired body depend, first, upon the composition—the content of grog, kaolin, ball clay, and feldspar; second, the sizing of the grog; third, the peculiar physical and chemical qualities inherent in primary kaolins as differentiated from the secondary ones, and in ball clays against the fire clays; fourth, the amounts and proportions of sodium silicate and carbonate of soda.

The following mixtures have been used successfully in the Pittsburgh Laboratory of the Bureau of Standards for the casting of glass pots:

Mixture No. 1.

	Per cent.
Whiteware-bisque grog	48
Feldspar	7
Kentucky ball clay, No. 4 or No. 6	11
Tennessee ball clay No. 5	11
Georgia, Florida, Delaware and North Carolina kaolins, 1/4 of each	23

Mixture No. 2.

	Per cent.
Whiteware-bisque grog	48.0
Feldspar	7.0
Kentucky ball clay No. 4	8.5
Tennessee ball clay No. 5	8.5
Georgia, Florida, Delaware and North Carolina kaolins, 1/4 each	28.0

[1] By permission of the Director, Bureau of Standards.

[2] A. V. Bleininger, *J. Am. Ceram. Soc.*, 1, 15–24 (1918); F. H. Riddle, this number, pp. 647–658.

Mixture No. 3.

	Per cent.
Whiteware-bisque grog	48.0
Feldspar	6.5
Kentucky ball clay No. 4 or No. 6	11.0
Tennessee ball clay No. 5	11.0
Kaolins, as before	23.5

Mixture No. 3 has been used more extensively than the others.

It is evident that the composition, in general, governs the final qualities of the pots, as is true of all ceramic bodies.

The sizing of the grog, in this case the waste bisque obtained from whiteware potteries, is quite an important factor. It is especially desirable to avoid too large a proportion of fines passing the 80-mesh sieve, since they promote vitrification too decidedly. While it is intended that the pot body should be dense and nearly non-absorbent, it is not good practice to develop a glassy structure. This objection would not hold if the grog possessed superior refractoriness and the fine particles by absorption became effective in increasing the rigidity of the mass. The mechanical analysis of the grog used corresponds fairly closely with the following sizing:

	Per cent.
Between the 10- and 20-mesh sieves	30
Between the 20- and 40-mesh sieves	40
Between the 40- and 80-mesh sieves	17
Through the 80-mesh sieve	13
	100

The physical and chemical qualities of the clays used are of evident importance with reference to their response to the effect of the alkaline electrolytes. The primary kaolins are most responsive, followed by the secondary kaolins, ball clays and fire clays in the order given. As a rule, the more plastic the bond clays, the smaller will be the amount of water required in the slip and the quicker the time of casting. Distinct differences were noted in the use of the several ball clays.

Slips have been made containing mixtures of three ball clays, Tennessee No. 5, Kentucky No. 4 and No. 6 in various proportions. The Tennessee No. 5 is generally very plastic and pos-

sesses good bonding properties; it increases the specific gravity of the slip and lowers the water content. At the same time it is effective in reducing the time of casting, lowering the shrinkage and the time of drying. It seems to be affected more profoundly by the reagents used. a fact associated with its fineness of grain and plasticity. The Kentucky ball clay No. 4 has fair plasticity and can be used to replace the Tennessee No. 5 clay more or less completely. It has been used alone to very good advantage but its slightly inferior plasticity necessitates the use of a larger quantity. The Kentucky ball clay No. 6 resembles a fire clay in its properties. Its plasticity and bonding power are lower than those of the preceding materials. In a slip containing some of this material the water content and shrinkage are higher, and the specific gravity lower. The strength likewise is decreased. It may be used because of its property of firing to a dense structure at lower temperatures.

From 17 to 22 per cent of ball clay has been used in our work, the higher amount giving better slips for casting. Definite limits regarding the use of any one ball clay can hardly be given since successive shipments rarely show the same physical properties. Any variation, therefore, might necessitate increasing or decreasing the quantity used. If several ball clays are used a slight change in the properties of one will not upset the working qualities of the mixture.

The presence of soluble salts in clays often causes considerable trouble in that the slips stiffen as soon as agitation ceases. It has been found desirable to add 0.01 per cent of barium carbonate with the alkaline electrolytes for the purpose of eliminating the soluble sulphates.

The use of the sodium carbonate and silicate has for its object reduction of the water content, formation of a dense, heavy slip, decrease of shrinkage, and the development of a capillary structure which makes possible increased speed and safety of drying. The amount of these salts which can be used varies from 0.20 to 0.33 per cent of the anhydrous compounds in terms of the dry weight of the clay and non-plastic materials. With any one composition the relative proportion of the two salts seems to be of greater im-

portance than the total quantity used. The proportion which has given the best results is 0.12 per cent of sodium silicate to 0.09 per cent of sodium carbonate. With this ratio the water content is approximately 22 per cent of the weight of the dry materials. A water content of 25 per cent was found to be required when the salts were added in the ratio of 1 : 1. It has been shown to be desirable not to introduce both salts at the same stage of the blunging. The silicate is dissolved in the water and then the dry body materials, thoroughly mixed, are added. This mixture is blunged to form a fluid slip and the carbonate is then added. The viscosity of the slip is increased somewhat by this addition of electrolyte. The increased "stiffness" of the mass seems to be apparent as a kind of stickiness rather than greater viscosity, due to coagulation, and the slip resembles heavy molasses. A further addition of silicate at this point lowers the viscosity, which indicates that the ratio of the salts is of primary importance.

The high viscosity desired is such that the pot will cast solid over night, in approximately 17 hours. The higher the viscosity, the slower is the casting of the slip, the greater the drying shrinkage, and the longer the time required for drying. With very viscous slips but little absorption of water by the plaster mold takes place—as the mass stiffens too quickly to permit of flow. However, with such a slip the pot does not become solid for some time.

With a slip of low viscosity considerable flow occurs, due to the absorption of water. An undesirable structure may develop when the slip passes down within the partially-stiffened outer portions of the pot wall. The less viscous slips, however, become solid in a shorter time and show a lower drying shrinkage. Control of viscosity must arrive at a compromise between the two extremes.

The time of casting is controlled to a considerable extent by the proportion of the two salts. With slips of practically equal viscosity an increase in the amount of sodium carbonate increases the time required for casting. Several attempts were made to cast pots using the proportion of 2 sodium carbonate to 1 of silicate. Very little or no casting occurred and the pots remained soft for 20

hours or more. They would crack in the mold and yet be too soft to allow the removal of the core. Pulling the latter would cause the pots to soften out of shape. On the other hand, with a proportion of 1 sodium carbonate to 2 of silicate, the slip was exceedingly heavy, with a specific gravity of 1.96, and yet of low viscosity. These slips did not stiffen, when allowed to stand, like those higher in carbonate. They permitted high absorption by the mold, showed low shrinkage, and cast solid in from 11 to 14 hours. The pots cast from these slips possessed a good exterior appearance but their internal structure showed much flow and lamination. The proportion of 4 sodium silicate to 3 of carbonate invariably gave the best results with reference to good casting quality, time of setting, moderate drying shrinkage, and satisfactory strength. The drying shrinkage of such pots is about 1.84 per cent in terms of the dry length and the burning shrinkage 6.82 per cent. The condition of the mold also affects the time of casting and, as is to be expected, the drier the plaster the more rapid is the absorption of water.

Summarizing these points regarding the casting of glass pots, it is apparent that the water content must be low, usually between 22–25 per cent in terms of the dry weight of the materials, the specific gravity of the slip from 1.90 to 1.95, and the viscosity quite high. The body thus produced must have low drying shrinkage and high mechanical strength. The amount of electrolyte varies from 0.20 to 0.33 per cent of the weight of the dry materials and the best ratio of sodium silicate to the carbonate is 4 : 3. An increase in sodium silicate decreases the water content, lowers the viscosity, and shortens the time of casting. An excess of it produces flow or laminated structure.

Kaolins respond most readily to the action of the alkalies, and fire clays least. In slips the use of a more plastic clay in place of a leaner one (fire clay) brings about higher specific gravity, shortening of the time of casting, decreased drying shrinkage, and increased strength. The use of several plastic clays is recommended and the introduction of a small amount of barium carbonate seems desirable.

BUREAU OF STANDARDS,
PITTSBURGH, PA.

CERAMIC ABSTRACTS.

General.

The osmotic purification of clay. W. R. ORMANDY. *Pottery Gazette*, **505**, 705–7 (1919).—The term "endosmosis" is illustrated as follows: If a glass vessel containing water is divided into two compartments by means of a porous diaphragm, and two oppositely charged plates are put in the compartments, it is found that the water will go up on one side of the diaphragm and down on the other. Furthermore, if one placed a battery of capillary tubes of extreme fineness under water and put two electric plates in the same, the liquid would move through the tubes. If the glass tubes were coated with sulphur on the inside the movement would be in the opposite direction. Count Schwerin, in experimenting to drive off water from colloidal peat (containing 95 per cent water), used a wooden screen with fine brass wire gauze. The peat was put in the screen and covered with an iron plate which acted as one electrode while the gauze acted as the other. A current of electricity was passed through same and immediately there was a rain-fall which in 20 minutes reduced the 5-inch layer of peat to $^1/_2$ inch. The layer of peat at the bottom of the screen acted as though it were a series of capillary tubes. Experiments with clay showed that some clays would collect at one of the poles while others would not. Many that would not in the natural state could be made to do so by deflocculation with alkalies. In cases where merely treating with alkalies did not help, the clay was first pugged with humus which aided the clay particles in picking up the sodium and then the clay could easily be collected on the poles. Clays purified and dried by this process are as dry as clays subjected to a pressure of 150 lbs. per sq. in. in a filter press. Drying of the clay is explained by endosmosis. The clay is first deposited on the drum in a thin layer which immediately forms a series of capillary tubes through which the water is driven out. Nearly all clay particles are negative. Silica is neutral and iron hydroxide is positive. By adding the right amount of alkali one group of particles could be neutralized giving off a charge which will excite the other particles. Pyrites can easily be separated from clay. Vitrification points may be lowered as much as 300° and the plasticity is increased. H. G. SCHURECHT.

Analysis of minerals and alloys of zirconium. A. TRAVERS. *Chimie & industrie*, **2**, 385–92 (1919).—Baddelyte, the principal Zr mineral, contains 75–98% ZrO_2 and as impurities SiO_2, TiO_2, Fe_2O_3, etc. Zircon, $ZrO_2.SiO_2$, contains in addition to the ordinary impurities rare earth phosphates. Before decomposing these minerals must be very carefully pulverized. Satisfactory decomposition cannot be brought about by fusion with KF, $KHSO_4$, Na_2CO_3 or KNO_3. Fusion with Na_2O_2 gives rapid and complete decom-

position. *Analysis of zirconia.* Fuse 1 g. finely powdered mineral with 10 g. Na_2O_2 in a nickel crucible. As this introduces Fe and Mn these must be determined on a separate sample fused in a porcelain crucible. Use separate samples for determination of Zr and Si. *Detn. of ZrO_2.* Treat fused mass with 300–400 cc. water, boil, filter on a large filter and wash with hot water containing 5% carbonate. Wash residue into a beaker and add ash of filter after igniting. Boil with excess HCl, add excess NH_4OH, filter, and wash with 10% NH_4OH solution. Redissolve in hot acid, cool, and neutralize almost completely with NH_4OH. Add excess $Na_2S_2O_3$, about 5 g. in 10% solution, boil till no more SO_2 is given off, filter and wash with hot water. Ppt. after ignition contains ZrO_2, TiO_2, and traces of SiO_2, Fe_2O_3, and Ni_2O_3. Transfer to a platinum crucible, add a few drops of water, 3–4 cc. HF, and 1 cc. H_2SO_4, evaporate to dryness, and calcine at a red heat to constant weight. Fuse residue with 10 g. $KHSO_4$, and dissolve in 10% H_2SO_4. Detn. TiO_2 colorimetrically on an aliquot part and Fe_2O_3 on another part. Detn. ZrO_2 by difference. *Detn. of TiO_2.* Add several cc. H_2O_2 to cold soln. and determine colorimetrically if present only in small amounts. The addition of large excess of H_2O_2 to soln. and boiling will precipitate all the ZrO_2. This can be used as a separation and gives a delicate test for ZrO_2, as 0.0001 g. in 30 cc. can be detected by this reaction. If TiO_2 is present up to 4–5% reduce with Zn and titrate with $FeCl_3$ using KCNS as indicator. *Detn. of SiO_2.* Decompose 1 g. sample as above, dissolve in HCl, evaporate to dryness, take up with HCl, and filter off SiO_2 rendered insoluble. To remove SiO_2 still in solution add excess NH_4OH to precipitate zirconia. Precipitate carries down all silica which is thus removed from presence of sodium salts and can be made insoluble. Dissolve precipitate in dilute HCl, evaporate to dryness, take up with HCl, and filter on same filter. Ignite to constant weight, and smoke off SiO_2 with HF in presence of H_2SO_4 as above. H_2SO_4 is necessary to prevent volatilization of ZrO_2 carried down by SiO_2. *Detn. of Fe_2O_3.* Decompose 1 g. material in porcelain crucible, take up with hot water, filter boiling, and dissolve residue in hot HCl. Boil off Cl set free by MnO_2 and titrate with $TiCl_2$ using KCNS as indicator. *Detn. of MnO_2.* Decompose 1 g. sample in porcelain crucible, take up with hot water, filter boiling, and dissolve oxides in HNO_3. Detn. colorimetrically after oxidation to permanganate by $K_2S_2O_8$ and $AgNO_3$. *Analysis of zircon.* After fusion of very finely ground sample in Na_2O_2 as above take up with water, filter, dissolve residue in HCl, and remove Ni by 2 precipitations with excess NH_4OH. Remove SiO_2 by evaporation in HCl soln., and exactly neutralize filtrate with NH_4OH. Add 5–8 g. pure oxalic acid, boil one-half hour, and allow to stand in cold for 12 hours. Wash precipitate of rare-earth oxalates with 10% oxalic acid in water, filter, ignite, and weigh as rare-earth oxides. Determine ZrO_2 in filtrate as above after recovery of ZrO_2 carried down by silica. This recovery is made by smoking off the silica with HF and H_2SO_4, fusion of residue in $KHSO_4$, dissolving in water, precipitating with NH_4OH and dissolving in HCl. *Detn. of alumina.* When present as in the analysis

of alloys of zirconium, alumina will be precipitated with the zirconia. It may be separated by fusion of the precipitate in pure KOH. After solution in water and filtering alumina is precipitated from the filtrate in neutral solution. The article also contains directions for the analysis of zirconium alloys. J. S. LAIRD.

Geological.

The sand and gravel resources of Missouri. C. L. DAKE. *Missouri Bureau of Mines,* **15,** *second series* (1918).—In 1907, O. U. Stromme commenced field mapping of the St. Peter sandstone with a view to getting out a report on the glass sand industry of Missouri. Mr. Stromme was called away from the work which was left until 1912 when it was resumed by Mr. Crane. After a short time he too was called away from the work and since 1913 Mr. Dake has continued the field work. The results of Mr. Dake's investigations which cover several years are embodied in this report which deals not only with the glass sand industry of Missouri but also contains data concerning all other sand and gravel deposits of that state. In this interesting report the general properties, origin and nature of sand are first discussed. The author then proceeds to consider the methods of handling the material and its uses and finally deals with the distribution of sand and gravel by geological formations and districts. In the portion dealing with distribution the various counties of the state are considered somewhat in detail with reference to sand and gravel resources. Numerous maps and illustrations are included in the report. E. D. ELSTON.

High-grade silica materials for glass, refractories and abrasives. R. J. COLONY. *N. Y. State Mus., Bulls.* **203, 204** (1919).—Due to conditions brought about by the war, many imports of refractory materials were either wholly prevented or seriously curtailed. Accordingly, domestic production of materials of this character was greatly stimulated. In the report by Colony, various geologic formations occurring in New York State are cited as being of economic value with reference to refractories and the glass industry. The most important of these formations according to Colony are as follows: The *Poughquag quartzite* in Dutchess and Westchester counties; the *Shawangunk conglomerate* in Ulster and Sullivan counties; *Oriskany sandstone* at Oriskany Falls, Oneida county; the *Potsdam sandstone* forming part of the Paleozoic fringe about the Adirondacks, and also occurring in the Mohawk Valley; the *Oneida glass sands* near Lake Oneida in Oneida and Oswego counties. Colony also states that materials might possibly be derived from the following formations in New York State; the *Whirlpool sandstone* at Lewiston, Niagara Falls, Niagara county; the *Oswego sandstone* at the falls of the Salmon River, in Oswego county; the *Oneida conglomerate* at Washington Mills, Oneida county; and a sandstone underlying the Lowville limestone occurring near Little Falls. The investigations are in general limited to the five formations first mentioned and the report is divided into two parts: (1) The rock and its structure are described briefly and there is

included a more detailed consideration of the lithologic character, chemical analyses and locality for each formation together with suggestions regarding facilities for working and transportation. (2) Tests made during the investigation are stated and mention is made of the various industries in which rock of the different formations might be used. Colony concludes that in the State of New York there are materials which might be used as follows: 1. *For glass making.* (*a*) The Potsdam sandstone of either the Johnstown district or the Moira-Bangor district. (*b*) The Oriskany sandstone, Oriskany Falls. (*c*) The Oneida glass sands. 2. *For ferro-silicon manufacture.* Rock from all the formations cited. 3. *For silica refractories.* (*a*) The Poughquag quartzite, especially a very pure variety occurring in Dutchess county. (*b*) Certain beds of the Shawangunk. 4. *For tube mill liners and pebbles.* (*a*) Especially that pure phase of Poughquag quartzite in Dutchess county. (*b*) Possibly the Poughquag quartzite near Peekskill. (*c*) Possibly certain beds of the Shawangunk. E. D. ELSTON.

Refractories.

Our present knowledge of refractory products. J. BIED. *Ceramique,* [1] **22,** 33 (1919).—Before the war the refractories manufacturers worked mostly on an empirical basis. Today they are improving their methods through technical aid. Already it is safe to predict that France will surpass Germany in this line of manufacture. Great credit is due to the work of H. LeChatelier and his co-worker Bogitch. The present article deals with basic, silicious, and silica-alumina products, little being known in France of the manufacture of the neutral refractories as chrome brick and bauxite. Dolomitic sand is very abundant in France. It is dead-burned in furnaces to a sufficient degree of heat to prevent hydration under ordinary atmospheric conditions for from two to three weeks, a long enough time to allow it to be placed in position for use in a furnace. Pure calcium lime air-slakes at a rate depending on its qualities and may reach temperatures up to about 400° C which is the temperature of dehydration of $Ca(OH)_2$. If the lime grains are large, hydration may be slow. Dead-burned dolomitic lime, however, slakes slowly in air and a year or two after placed in the furnace wall causes much trouble by expansion. Several per cent of iron carbonate or 5 to 6% of kaolin or both materials added together prevent slaking. After being dead-burned the dolomitic sand, or rock, is ground to two sizes, one of flour fineness, the other of size of particles all passing through a sieve of 5 to 6 mm. openings. 30 to 40% of fine-ground and 60 to 70% of coarse-ground material are mixed for making brick or for tamping in place in monolithic construction. The dead-burned material may begin to slake in two weeks, the brick in less time, hence requiring immediate placing for use in a furnace. For monolithic construction the finely-ground, burned dolomite is mixed with tar which has been boiled five hours. The tar with this treatment is very viscous and forms long tough threads which help to hold together the mass of the tar-dolomite mixture. If desired, the mixture may be molded

into brick in a press at a pressure of 400 to 500 kg. per sq. cm. After 4 to 5 hours the brick become quite hard. They must be put in place within 2 to 3 days and burned to a clear red heat. Special forms as those for the bottom of the Bessemer furnace are molded in cast iron forms and the whole placed in reverberatory furnaces and burned to 900° or 1000° C for 8 to 10 days. A converter cover prepared in this manner lasts for from 140 to 150 charges. Before the war all the magnesia used in France came from Styria, Austria, some in bulk form and some as brick. The compositions indicate that artificial cement was added to the magnesite for making brick. The 6 to 8% of Fe_2O_3 in the Styrian magnesite prevents slaking to a great degree but lowers the resistance to deformation at high temperatures. The relation between temperatures and resistance to deformation is shown by a diagram of H. LeChatelier and B. Bogitch (*Compt. rend.*, **165**, 488 (1917) Specimen No. 1. See Ceramic Abstracts in this number). The figures show that the Styrian brick suffers its greatest loss of strength between 1300° and 1400° C. During the war, magnesite has been obtained from Euboea, Greece and made into brick in France. The compositions of the raw materials and of the brick are as follows: No addition to the raw material is made.

MgO	80–85
CaO	4.5–5.5
Fe_2O_3 and Al_2O_3	1.5–2.0
SiO_2	7–8

The degree of calcination is determined from the sp. gr. That of the raw material is 3.92, of the burned 3.4 to 3.5. The calcined product is used in mass construction by mixing with 8–10% of well-boiled tar, the mixture heated to 300° C then pounded into place with tampers heated to dull red heat. For brick two sizes of the burned material are used. The mixture is composed of 2 parts of material less than 5 to 6 mm. in size and 1 part impalpable powder. The relation between crushing strength and temp. of the Grecian brick is shown as Sample No. 2 in the article by LeChatelier and Bogitch already referred to. This brick suffers its greatest loss of strength between the temps. of 1400° and 1550° thus being of much higher resistance than Styrian brick up to 1550°. At this temperature both have practically zero crushing strength. The Grecian brick has the disadvantages of continued shrinkage at prolonged high temps., and ready slaking in air on account of the low amounts of flux. The brick disintegrates in water vapor in 2 to 20 hours. Certain of the commercial brick produced in France were burned in an electric furnace. At the beginning of the burn the porosity was 20%. At the end the porosity was 11% and the volume shrinkage 16%. The porosity should be reduced to a certain minimum but not too low. Italian magnesite is also now used in France. Typical compositions of the dead-burned material and of the brick are given below.

	Dead-burned	Brick
SiO_2	8.9	5.15
Al_2O_3	0.27	0.75
Fe_2O_3	1.98	6.00
CaO	4.50	3.37
MgO	85.25	84.00

It is seen that Fe_2O_3 is added for making brick. The Italian magnesite contains many silicious and calcareous concretions which have to be picked out after calcination. This is, however, not a prohibitive handicap for the use of this material. Eight photos are given of plant operations in French factories. F. A. KIRKPATRICK.

Properties of magnesia refractories. H. LECHATELIER AND B. BOGITCH. *Compt. rend.*, **165**, 488 (1917).—6 magnesite and 1 chrome brick were studied. Table 1 describes the brick, Table 2 gives chemical compositions, Table 3 gives crushing strength at different temperatures.

TABLE 1.

Materials Investigated.

No. 1. Styrian brick, burned to 1450° C, made in 1890.
No. 2. Brick of good quality from Euboea, Greece, made in 1910.
No. 3. Brick G of good quality from commercial plant.
No. 4. Brick B, of low quality, containing an addition of 3% calcined pyrites to the mixture.
No. 5. Pure magnesia, melted in the electric furnace and contaminated in the process.
No. 6. The raw material of Brick B, burned in the electric furnace.
No. 7. Chrome brick.

TABLE 2.

Chemical Analyses.

	1.	2.	3.	4.	5.	6.	7.
MgO	86.7	93.4	89.4	81.2	93.7	88.5	12.3
CaO	1.0	3.7	4.5	4.8	2.7	4.5	5.8
Fe_2O_3	6.0	0.5	1.1	4.2	0.3	1.4	15.5 (FeO)
Al_2O_3	0.6	0.2	0.8	1.0	1.1	0.0	10.9
SiO_2	6.7	2.8	4.2	8.8	3.2	6.5	4.7
Cr_2O_3	..	..	..	..	..	..	50.0
Mn_2O_3	..	..	..	..	..	..	1.5

TABLE 3.

Crushing Strength in Kg. per Sq. Cm.

No.	15° C.	1000° C	1300° C.	1500° C.	1600° C.
1	145	85	66	3.6	1.8
2	420	...	..	185	8.0
3	390	...	..	90	4.8
4	230	...	..	16	3.5
5	...	...	..	90	6.6
6	530	...	..	...	3.5
7	260	120	6	2	1.0

Additional values determined for Nos. 1 and 2 may be read approximately as follows from the curves given:

No. 1—800°, 110 kg.; 1200°, 82 kg.; 1340°, 25 kg.; 1200°, 6 kg.
No. 2—1400°, 250 kg.; 1550°, 30 kg.

There was found to be for all the samples a rapid decrease in strength throughout a certain narrow temperature range, the temperature depending upon the purity of the material. The results explain the reason for the better resistance of silica brick in the walls of a furnace, since the silica refractories have higher fusion points, and greater strength at the higher temperatures.

F. A. KIRKPATRICK.

Notes on refractory materials. J. W. MELLOR. *Pottery Gazette*, 503, 493, 494 (1919).—The great bulk of refractories originate from fire clay. The first test to be made in testing fire clays is the cone test because of its cheapness and rapidity. Chemical and rational analyses are desirable. Best results in rational analysis are obtained by calculating same from the ultimate analysis. By calculating the chemical formula with alumina as unity, Ludwig found a relation between refractoriness and composition which was found to agree with nearly 70 British clays—there being only three exceptions. This applies to only the high-grade clays. The heating of alumina causes its specific gravity to increase from 2.8 at 600° C, to 3.8 at 1200° C, with a shrinkage of 30 per cent. Fused bauxite is used in France to make brick under the name "corindite." The presence of ferric oxide acts as a stimulant in converting quartz to a low specific gravity form. Excellent silica brick are made in South Wales with 5% ferric oxide. Dusts of the oxides of zinc, copper, and iron in a reducing atmosphere penetrate rapidly into firebrick and there is evidence of volatilization of metals at unexpected low temperatures; copper at 600° C and iron at 1100°. When coal is salty the volatile salt is active in forming a slag with the clay. Regarding thermal conductivity Mellor agrees that porous materials have a low conductivity at low temperatures but believes that at high temperatures a highly porous structure favors conductivity—due to convection of heat.

H. G. SCHURECHT.

Silica refractories. Factors affecting their quality and methods of testing the raw materials and finished ware. D. W. Ross. Bur. Standards, *Tech. Paper*, **116** (1919).—A review of the literature is given, particularly the recent articles by McDowell, and Nesbitt and Bell. Inversion temps. of quartz, tridymite and cristobalite are discussed. Eutectic points of lime-silica, alumina-silica and lime-iron oxide curves are given. In a review of the geology of quartzites, chalcedony, etc., it is stated that the order of merit for silica refractories is chalcedony, old quartzites and vein quartz. The Medina or Tuscarora formation in Penn. supplies over half the rock used in U. S. for silica refractories. The rock is crushed in a wet-pan and 2% CaO by wt. is added. When thoroughly mixed, the bricks are molded by hand, hot-air dried and burned to cone 14–18. In European countries bricks are made containing 96% silica, about 1.3% or less of lime and a little highly silicious clay. Silica bricks are used in regenerative and coking chambers of by-product coke plants; tops, ends and sometimes, walls of open-hearth furnaces, etc. A number of heating tests were made on raw quartzites, raw commercial brick mixes, commercial brick and special mixes, to determine the amount, speed and nature of vol. changes caused by various heat treatments. The leading varieties of silica brick made in U. S. were subjected to analyses and softening temp. tests, load tests and vol. changes at 300° C, micro studies, slag tests, screen analyses, cold strength tests, and vol. change tests. Voluminous data for all these tests are recorded. Rates of transformation of different materials to cristobalite on heating to 1400° are in the order: amorphous silica, chert, chalcedony and quartz glass. All are transformed at about equal speed and addition of lime hastens transformation while plastic clay has no effect. Due to small percentage of flux, quartzite is transformed to cristobalite in burning but after 70% has been inverted, tridymite makes its appearance and develops slowly with continued heat treatment. Excepting special cases, the sp. gr. of silica brick is between 2.65 and 2.27, and sp. gr. determinations show the degree of burning the brick has had. In burning, the vol. of solid material increases 10–15%. The average brick contains about 27% pore space and the porosity of burned brick is greater than that of the raw mix. Minimum porosity can be obtained by raising the temp. at the usual rate to 1250–1350° and holding for several days. Transformation of quartz will then proceed at moderate rate and the soaking will permit the fluxes to exert maximum effect in drawing the materials together, thus keeping increase in pore space down to a minimum. The temp. should finally be raised to cone 18–20. The chief thermal volume changes in silica brick are due to tridymite inversions below 200° and the alpha-beta cristobalite inversion at 220–300°. Practically all spalling occurs between atmospheric temp. and 300° and silica brick when heated in a load test show marked volume expansion in this temp. range. Strength tests show lack of uniformity. A mix which yields satisfactory results shows the following screen analysis: residue on 8-mesh 15.3%, 16-mesh 13.4%, 20-mesh 4.6%, 30-mesh 5.4%, 40-mesh 4.8%, through 40-mesh 56.5%. Cross

breaking tests indicate that with bricks made from quartzite, the strength of slightly to mediumly burned brick depends upon the state of metamorphosis of the raw material, porosity of the raw brick, and the lime-silica bond formed on burning. Hard-burned brick seem to have their strength increased by the formation, through transformation of quartz, of interlocking crystals. To resist attacks of basic slags, etc., silica brick should have as low porosity as possible and contain as large an amount of large fragments as possible, for it seems that small particles are fluxed away before large particles are attacked. An all-tridymite brick does not seem commercially probable. 6–8% lime increases the speed of the quartz inversion and does not appreciably lower the fusion point. *General characteristics* of best grade silica refractories: (1) Shall contain not less than 95% SiO_2. (2) Fuse not lower than cone 31. (3) Sp. gr. shall not be above 2.384. (4) Permanent exterior vol. expansion at 1500° for $1^1/_2$ hours shall not exceed 6%. (5) Strength tests shall show average modulus of 540 and effective modulus of rupture of approximately 284. (6) Under 25 lbs. load at 1500° for $1^1/_2$ hours, shall not exceed 2% increase or 1% decrease in length.

EARLE N. JESSOP.

Glass.

The attack of pots for glass melting. W. ROSENHAIN. *Engineering, (L) V.*, **107**, pp. 725–7.—The effect of flint, soda-lime and other glasses on small clay pots of purest china clay was studied. Cuts show effect of attack of glasses of different densities. Dangers possible from the use of local protecting devices for pots are also brought out. CHESTER TREISCHEL.

Cement and Lime.

Portland cements. E. CANDLOT. *Chimie & industrie*, **2**, 371–84 (1919).—Recent developments in portland cement manufacture are reported, in connection with processes of burning and grinding. The rotary kiln which is so largely used mainly on account of the high quality of the cement produced is very uneconomical as regards fuel, requiring 25–35% of the weight of cement produced of a good grade of coal. Two types of stationary shaft-furnaces have been developed to a point where they produce cement of quality equal to that produced by the rotary kiln, but with a fuel consumption of only 14–16%. The finely ground raw mix is mixed with the fuel, which may be coke breeze or culm, and compressed into briquettes. The largest kilns of this type produce only 50 tons per day and considerable labor is required in forming the briquettes and discharging the clinker as mechanical processes for emptying the kiln have not yet been perfected. The cost of these operations does not nearly equal the saving in fuel and in power required to rotate the rotary kiln. "Compound" tube mills for grinding the clinker are proving very economical. The largest of this type grinds 10–12 tons an hour and consists of a cylinder divided into two compartments by a cross partition provided with sieves to permit the passage of the rough-ground material

to the finishing compartment from the first or rough-grinding compartment. The latter is half filled with steel slugs, while the finishing compartment is provided with flint pebbles. Calcium-aluminate cements have been made by fusing lime and bauxite together. Such cements cannot be made in the rotary kiln and their hydraulic properties are not destroyed by fusion. They are slow setting (4 hours) but harden very rapidly, 1:3 mortar giving a strength of 450–525 pounds per square inch in 24 hours. Very low-limed cement of composition SiO_2 10%, Al_2O_3 40%, Fe_2O_3 10%, CaO 40% made in this way appear to be very resistant to the action of gypsum and sulphate solutions. J. S. LAIRD.

New plant of the Kelley Island Lime and Transport Company. COMPANY-STAFF ARTICLE. *Concrete Cement Mill Section*, **14**, 49 (1919).—This plant is located at Buffalo, N. Y. and is one of the most modern in the country. There are many special features. Limestone is to be brought by boat from Kelley's Island, Ohio, and Rogers City, Mich., and unloaded at the dock into a storage pile. It will be dried as needed by a rotary dryer fed by an under-fed stoker. All dust is removed by a centrifugal dust collector and sold as asphalt dust. The stone is then ground in Kent Mills and screened to different sizes for agricultural uses. That portion of the material from $^3/_8$ to $1^1/_4$ inches in size of particle is conveyed to a bin above the rotary kiln. This kiln is 8 ft. in diameter and 135 ft. long and requires three hours for the transit of the lime through it. It is fired by gas producer and the waste gases are used for generating 200 h. p. of steam. The burned lime passes through an open bucket elevator into a rotary cooler and into a storage bin. It is sold in bulk or hydrated. For the latter process a Schaffer automatic hydrator is used. The hydrated lime is passed through Raymond mills and dust collectors and elevated to storage bins above the packing machines. No large lump lime will be produced as only small-size material can be burned in the rotary kiln. F. A. KIRKPATRICK.

The cause of unsoundness in cement. B. F. ERDAHL. *Concrete Cement Mill Section*, **14**, 27 (1919).—It is intended to disprove the assumption that excess of free lime causes unsoundness of portland cement. (1) Lime slakes quickly and there is sufficient water present in the pat used for the test. (2) The rotary movement of the kiln causes sufficient mixing to prevent enclosure of free lime in the clinker. (3) A small ball or particle of free lime could not possibly pass through intense grinding without undergoing at least slight fracture which offers opportunity of slaking on addition of water. (4) 2.7 to 16.7% of free lime (CaO) were added to a sound cement. All the mixtures were O. K. in the soundness test. (5) An unsound cement was ground to pass 200-mesh sieve. After one month in an air-tight bottle it passed the soundness test. (6) Dusted clinker was tested. The fused outer shell was sound, the enclosed dust was decidedly unsound. Chemical composition indicated outer shell to be $3CaO.SiO_2$ and $2CaO.SiO_2$. (7) The conclusion is that the cause of unsoundness is under-burning, with the formation and subsequent decomposition of $2CaO.SiO_2$. No discussion is given of the probable effect of MgO or of alkalies on soundness.

F. A. KIRKPATRICK.

CERAMIC PATENTS.*

G. E. MIDDLETON, *Abstractor.*

Glass gathering machine and process. J. O. HENSEN and J. HENLE. U. S. 1,304,568, May 27, 1919. This invention relates to a machine and process for gathering glass with a punty as distinguished from those machines and processes in which suction means and ladling and flowing devices are employed. The machine is designed so that the punty is manipulated in a manner closely approximating manual manipulation whereby uniform gathers, free from blisters, are obtained, and yet the gathers for each weight of bottle or other article to be produced are said to be of substantially unvarying amount and more uniform as to weight and form than those incident to hand-gathering.

Glass. E. C. SULLIVAN AND W. C. TAYLOR. U. S. 1,304,623, May 27, 1919. This glass is especially adapted for fabrication into pressed or blown ware intended for culinary or laboratory uses and is said to possess a high coefficient of thermal endurance and high stability, that is, power to resist chemical attack. It is, generally speaking, a boro-silicate having a linear coefficient of expansion less than 0.000004, a thermal conductivity as high as 0.0028, a molecular ratio of silica to base greater than 13 to 1, and a molecular ratio of acid oxide or oxides to basic oxide or oxides of not less than 15 to 1. The following are examples:

	A.	B_1.	B_2.	C.	D.	E.
SiO_2	70	80.6	80.9	90	85	90
B_2O_3	20	13	12.9	6	12.5	5
Na_2O	4	4.4	4.4	3	1.5	...
Al_2O_3	6	2	1.8	1	...	2
Sb_2O_3	...	...	...	...	1	..
Li_2O	...	...	...	...	...	3
	100	100	100	100	100	100

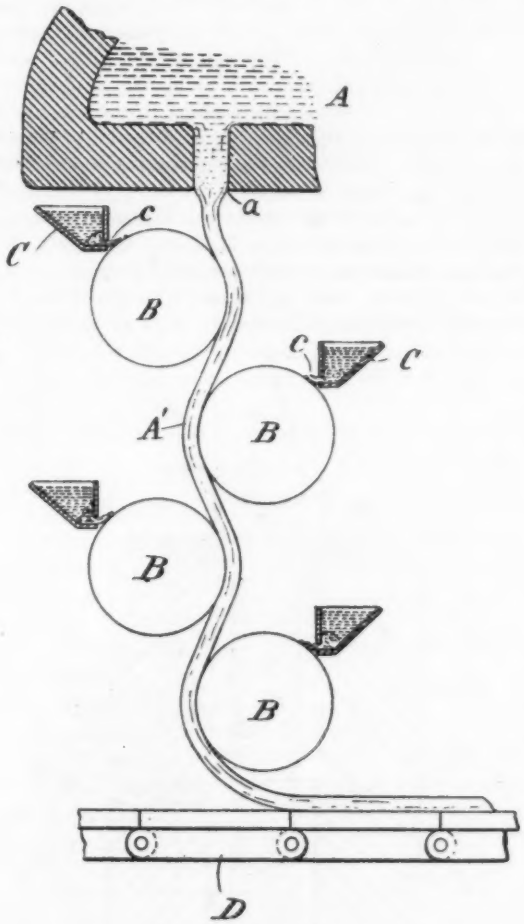
Glass B_2 is said to have gone into extensive commercial use in the manufacture of baking dishes and chemical ware.

U. S. 1,304,622 relates to baking dishes made of this glass.

Process of manufacturing sheet-glass. E. HOPKINSON. U. S. 1,305,286, June 3, 1919. Sheet glass is made by causing a stream of molten glass to flow from a source of supply A (see Fig.) free from any contacting surface and then causing it to travel in a sinuous path and thereby effecting surface formation

*NOTE.—Copies of thsee patents may be secured for five cents each by application to the Commissioner of Patents, Washington, D. C.

on both sides, the concave devices being in contact with forming devices B and the convex surfaces being free during said travel. The forming rolls B



are lubricated at C by means of water or other suitable liquid. Sheet glass made by this process is said to be superior to the ordinary cylinder glass and to approach plate glass in its optical quality.

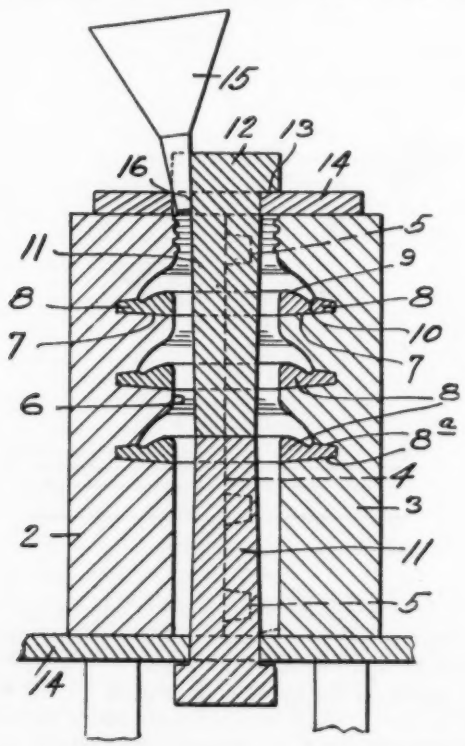
Process and apparatus for drawing sheet-glass. J. H. KENDIG. U. S. 1,305,288, June 3, 1919. Sheet glass is drawn over a horizontally rotating cylinder, the surface of which is of charred bass wood. This cylinder is placed at the delivery end of the tank with its axis at the level of the glass

and by rotating faster than the movement of the glass being drawn, has a polishing action.

Glass. H. P. GAGE AND W. C. TAYLOR. U. S. 1,305,793, June 3, 1919. A glass which has high transmission for the ultraviolet rays while absorbing practically all of the visible light. The most desirable results are obtained by a glass of the following composition: SiO_2 50%, K_2O 16%, BaO 25%, NiO 9%. The amount of infra-red transmitted varies with the amount of nickel and the thickness of the glass. If it is desired to reduce the transmission of the red without increasing the percentage of nickel oxide, a small percentage of cupric oxide may be added.

U. S. 1,305,794, is similar to the above but is limited to a zinc glass, an example of such a glass being SiO_2 53%, K_2O 20%, ZnO 15%, NiO 12%.

Mold for forming insulators or other porcelain objects. C. J. KIRK and G. BRAIN. U. S. 1,304,571, May 27, 1919. This invention relates to the molding of porcelain insulators of "umbrella" type for high tension circuits.



The difficulty of casting the under-cut umbrella sections is overcome by the use of longitudinally split molds 2 and split annular removable cores 8 (Fig.)

Continuous kiln. H. WEBSTER AND W. B. KINCAID. U. S. 1,304,831, May 27, 1919. This is a continuous kiln of a modified ring type, consisting of two longitudinal parallel subdivided chambers communicating with each other at either end. The bottom is divided into troughs which communicate with the main draft flues and into which fuel is fed through the crown. The longitudinal chambers are divided into compartments by means of temporary partitions of green brick which terminate short of the crown and, hence, force the products of combustion to pass in proximity thereto. Temporary paper partitions are used in conjunction with the first mentioned partitions in the usual way.

Continuous brick kiln. W. W. DICKINSON, JR. U. S. 1,305,447, June 3. 1919. The permanent flue structure of this kiln is all underground, the kiln itself being temporary and similar to the old scove kiln. It is a continuous kiln of a modified ring type, consisting of two parallel chambers communicating with each other at either end, each of which is divided into several compartments. The gases pass from one compartment to the next downwardly through vertical passages built of burned brick, but filled with green ones. The fuel used is gas or oil.

Manufacture of bricks and furnace-linings from dead-burned magnesite. S. G. MCANALLY. U. S. 1,305,475, June 3, 1919. Dead-burned magnesite bricks containing 15 to 18% lime, 6 to 6.5% silica, and 8 to 8.5% iron oxide and alumina are made by dead burning magnesite with lime, iron oxide and silica, grinding the resultant product to a powder, mixing with water, molding into shapes and drying and burning at a high temperature. This material is said to be highly refractory, inert to the corrosive action of slags, limestone and molten metal, not to slake with water and to set or bind at a temperature slightly above the normal working of a steel furnace without the addition of other materials.

Diatomaceous composition. T. M. CAVEN. U. S. 1,305,522, June 3, 1919. This composition is suitable for use in making partitions, roofing, and for insulating purposes, especially where lightness is a desideratum. It is made by grinding diatomaceous material in water to plasticity, burning this product to the desired degree of hardness, crushing it and then adding one part by weight of Portland cement to two parts of the calcined diatomaceous earth and sufficient water.

AMERICAN CERAMIC SOCIETY.

The Summer Meeting.

April 4–7, 1919.

The lobby of the Iroquois Hotel, Buffalo, during the forenoon of August fourth, presented a scene familiar to those who attend ceramic meetings. S. C. Linbarger and other members of the local committee had their table in the center and were busy registering the members as they arrived. After registration came lunch and the distribution of tickets for the evening dinner and the Tuesday excursion. The party then took street cars for the Pierce Arrow Motor Car plant. The tour through the factory was rather too hasty to suit the more inquiring but it left time for visits to the Albright Art Gallery and other places of interest. Dinner was served promptly at seven in a private room and about sixty sat down to an excellent repast. Singing popular and familiar songs enlivened the occasion and a short time was devoted to speeches which were very informal, as the evening was to be used for meetings of the professional divisions and the Board of Trustees.

Tuesday was Niagara Falls day. The trip was well arranged by the local committee and the tickets included all charges for the day. The journey was made in three motor omnibuses along the famous brick-paved boulevard, and the city of Niagara Falls was reached about eleven o'clock. The first visit was to the Shredded Wheat plant, noted for its accommodations for visitors, its perfect sanitation, and its wonderful automatic machinery. From this point the party went to the Power Houses and inspected the colossal installations of penstocks, turbines, and generators, by means of which the power of the Falls is harnessed and converted into electrical energy.

Lunch was served on the cafeteria plan at the Chamber of Commerce, after which Mr. Harper, chief engineer of the power company, explained the principles governing the utilization of the Falls and told of schemes of advancement.

The famous Falls were then visited and stops were made at the points of vantage. Crossing the International bridge, the party took a special car to Niagara Glen, through which they were conducted by Mr. Morphy, who has the reputation of knowing every stone and plant in the glen. The varieties of botanical growth were explained and the geological formation was discussed, including the remarkable pot-holes for which the locality is famed.

A sumptuous dinner was served at the Clifton House on the Canadian side, overlooking the Horseshoe falls, and the return journey to Buffalo was made in the cool of the evening.

On Wednesday morning the street cars took the members to the Buffalo Pottery, where they were met by L. H. Bown, general manager, W. J. Rea, superintendent, and other members of the staff. A thorough inspection of the plant was made, special interest being evoked by the electrically driven machinery, the newly installed driers for jigger work and dipping, and the roller machine for underglaze printing. The greatest courtesy was shown by the officials and this proved to be the most profitable and enjoyable visit of the trip.

Next in order was the great Larkin plant in which a great variety of soaps, perfumes, spices, and household supplies are produced or prepared. The automatic machinery proved most interesting and opened up numerous possibilities in view of the present shortage of labor. Before inspecting the plant the party was entertained at luncheon by the Larkin Company and during the meal a motion picture film was shown illustrating the "Larkin idea." Mr. J. D. Larkin, the head and originator of the firm, spoke a few words of welcome to the members.

The huge plant of the Lackawanna Steel Company was next visited and the operations of steel manufacture were followed with interest. The Bessemer converter, always spectacular, delivered its Niagara of sparks and glowing ingots were transformed by the rolls into fiery serpents.

The boat "City of Buffalo" of the C & B Line transported some forty-five of the crowd to Cleveland, over a calm lake illumined by a half-grown moon. Cleveland was reached early Thursday morning and at the Hotel Cleveland an additional number of members was met. A local committee had here made excellent

arrangements and after a welcome breakfast automobiles and street cars transported the visitors, some to the research laboratories of the National Lamp Works at Nela Park, and some to the plants of the Enamel Products Company and the Cleveland Metal Products Company.

At Nela Park the party was met by a guide who explained the interesting historical collection which showed the evolution of the electric lamp in all its parts. They were then conducted to the auditorium where a film was shown which illustrated in great detail the winning of the raw materials and the manufacture and assembling of the modern lamp. It was explained that, as the manufacture was carried on as to the various parts in widely separated parts of the country, it would be manifestly impossible to view the actuality, and in fact the film showed the details in the most thorough manner. At the same time some regret was expressed that the laboratories themselves were not opened for inspection.

About twenty-five persons were driven to the plant of the Enamel Products Company, where Leon J. Frost conducted the party through the factory and explained the details of the manufacturing process. Following this, the plant of the Cleveland Metal Products Company, one of the largest producers of high grade enamel ware in the country, was visited. Before going into this plant it was announced that those going through thereby granted permission for a representative of this company to visit their plants in return. All agreed readily to this proposition. The equipment and grade of ware made in these two plants are fully up to the standard of enameling concerns in this country.

Thursday afternoon was given over to gaiety. The scene was the Cleveland Yacht Club, situated by Rocky River, about ten miles west of the city. The Divisions on Glass and Enamel took advantage of the occasion to hold meetings but these did not interfere with the fun. Several donned bathing suits and disported themselves in the water. Others organized a baseball game in the court with F. G. Lord and F. W. Walker, Jr., as captains. Hits and runs were many and the final score was 19–15. The winning team had some advantage by virtue of being on the Lord side.

Dinner was served, with the compliments of the Northern Ohio Section, and was accompanied by dancing. This was followed by "retreat" by the local Naval Boy Scouts, with the sunset gun and the lowering of the flag. Some of the party then returned to the city, while others continued to dance until a late hour.

The local committees are to be congratulated upon very excellent arrangements and efficient management. The Summer Meetings are necessarily becoming more and more social in their nature, as there is increasing difficulty in obtaining admittance to scientific establishments, but the meeting this year combined both elements in a very happy way.

CHARLES F. BINNS, *Secretary.*

ACTIVITIES OF THE SOCIETY.

Actions taken by the Board of Trustees at a meeting held at the Hotel Iroquois, Buffalo, N. Y., Monday evening, August 4, 1919. Those present were R. T. Stull, Pres., R. H. Minton, Vice-Pres., R. D. Landrum, M. F. Beecher, H. F. Staley, Chas. F. Binns, Secy., Norah W. Binns, Assistant Sec'y.

1. It was voted that, for the present year, 10 per cent of the dues and fees, as of 1919, paid by a member of the Society, who has or shall become a member of a professional division, be allotted to that division for legitimate divisional expenses, such as postage, stenographic services, stationery, printing, and multigraphic work. An accounting of money expended shall be rendered by the Secretary of each division to the Secretary of the Society at the end of the fiscal year.

(NOTE.—In the case of a member who wishes to belong to more than one division, he shall designate his "major" division, and 10 per cent of his dues and fee shall be allotted to that division.)

2. It was voted that the purchase of other volumes in order to obtain those low in stock shall be left to the discretion of the Secretary, it being the sense of the Board that such purchase is wise.

3. It was voted that the list of members of the Society shall not be available to anyone not a member, and that the Year Book shall not be sold separately.

4. It was voted to create a department in the Journal, of $^1/_2$" single column advertising, free to members of the Society, for ceramic employers wishing men, and men wishing ceramic positions.

5. It was voted to amplify the booklet on the scope and purpose of the Society and to keep a supply constantly available.

6. Mr. F. H. Riddle was appointed chairman of the Membership Committe in place of Mr. R. C. Purdy, resigned.

AMERICAN CERAMIC SOCIETY.

Acquisition of New Members during July, 1919.

Resident Associate.

Back, Robert, Haeger Potteries, Dundee, Ill.
Crimmel, A. C., Sneath Glass Co., Hartford City, Ind.
Crimmel, H. H., Sneath Glass Co., Hartford City, Ind.
Denk, F. J., 1216 House Bldg., Pittsburgh, Pa.
Fuller, Donald H., Bureau of Standards, Pittsburgh, Pa.
Houk, F. J., Illinois Pacific Glass Co., San Francisco, Cal.
Kimes, A. W., 733 Summerlea St., Pittsburgh, Pa.
Middleton, George E., U. S. Patent Office, Washington, D. C.
Stewart, John G., 530 Union Trust Bldg., Cincinnati, Ohio.
Young, Everett T., Peekskill Fire Brick Works, Peekskill, N. Y.

Foreign Associate.

Murai, S., Ceramic Dept., Central Laboratory, South Manchurian R. R., Dairen, South Manchuria, China.
Page, Howard E., China General Edison Co., Inc., 15 Robinson Rd., Shanghai, China.
Pitt, H. H., Christon Bank, Lesbury, England.
Shanks, Ronald J., Dalmeny Barrhead, Scotland.

NOTICE.

The addresses of the following members of the Society are unknown. Any information sent to the Secretary at Alfred, New York, will be gratefully received.

Kenneth R. Ayer	**Max Dorst**	**G. A. Murray**
Harold A. Best	**Robert W. Earle**	**L. Zach Olsson**
R. E. Brown	**Robert F. Ferguson**	**G. M. Raymond**
L. R. Bucher	**Herman A. Hall**	**Geo. M. Schaulin**
John A. Chase	**A. V. Henry**	**H. H. Sortwell**
Harold E. Clark	**E. A. Maddison**	**Wm. W. Stanley**
May E. Cooke	**Joseph A. Martz**	**Thomas N. Horsley**
Jack M. Dell	**T. C. Moorshead**	**C. E. Ramsden**

$6,831.35

The Value of Fuel Saved in One Year

¶ Actual records were kept for 365 days of the burning of 9-inch, high-grade, refractory brick in one continuous tunnel kiln and in seven 30-foot round kilns, during which time 5,110,000 brick were burned in the tunnel kiln as against 5,040,000 in the seven round kilns.

¶ But this isn't all—the actual labor saving amounted to $5,808.00. Taking into consideration the necessary items of depreciation, interest on plant, maintenance and repairs, the average yearly cost for burning 1,000 brick in the continuous tunnel kiln system was $2.95 as against $6.20 in the round kilns.

¶ If you are really interested in the greater efficiency of burning, you will let us tell you more about the actual accomplishments of

The Didier-March Continuous Railroad Tunnel Kiln

Didier-March Company

GEO. A. BALZ *Gen'l Mgr.* **Perth Amboy, New Jersey** LOUIS A. WITTE *Chief Engineer*

Contractors *Manufacturers of Refractories* *Engineers*

The Mechanical Weather Man says:

"YOUR GREEN MOLDED or FORMED PIECES dry beautifully on certain days during the year, don't they?

"Well, all I do is simply reproduce those days ***every*** day. And applied to the drying of ceramic ware, my system, at less cost than any other method, produces a uniformly superior piece in a positive, automatically controlled drying time.

"If your checks are from 20 to 30% now, I can reduce them to 2 or 3%."

Carrier Engineering Corporation

39 Cortlandt Street, New York

Boston **Philadelphia** **Buffalo** **Chicago**

Ask me for bulletin 100. It tells you how I manufacture weather to order.

Write right now.

The Mandle Clay Mining Company

ESTABLISHED 40 YEARS *OFFICE: ST. LOUIS, MO.*

Mines Located in Tennessee and Kentucky

Our materials STANDARD for manufacturing every line of product in which are used BALL, WAD, SAGGER, and HIGH GRADE REFRACTORY BOND CLAYS.

For Pottery and Porcelain of all kinds
For Glass Industries and Crucible Manufacturers

Quality *Uniformity* *Experience*

Edgar QUALITY *Clays*

REALLY washed—Highest percentage clay substance

Brands	Produced by
Edgar Florida Kaolin	*Edgar Plastic Kaolin Co.*
Edgar Georgia Paper Clay and Kaolin	*Edgar Brothers Co.*
Lake County Florida Clay	*Lake County Clay Co.*

One Management—Office, Metuchen, N. J.

Zwermann *Twin* Tunnel Kiln

Note Its Chief Advantages:—

First:—The first cost of this kiln compared with a single tunnel of the same capacity is considerably lower. It requires less brick, one-half of the buck stays, less space, and no side or return track.

Second:—This twin tunnel kiln allows a greater utilization of the fuel than a single tunnel kiln, as the heat from cooling ware is used for water-smoking the incoming ware.

Third:—This kiln allows an absolute and positive control of the firing zone, and in the firing zone a reducing or oxidizing condition can be maintained at will.

Fourth:—The cooling of the ware as well as the water-smoking and pre-heating in this kiln are absolutely automatic. It is impossible to get the receiving end of the tunnel too hot.

Fifth:—This kiln will save about 50% on labor and from 65% to 75% on fuel as compared with periodic kilns. Burning time is cut down by ⅓ to ½. Where saggers are used, they will last twice as long.

Carl H. Zwermann **Robinson, Ill.**

NOTICE

In order to increase the stock of certain volumes of the Transactions of the American Ceramic Society, the Secretary of the Society has been authorized by the Board of Trustees to purchase a limited number of copies of Volumes II, V, IX, X, XII, and XIX, at five dollars each. Members or former members who are willing to dispose of their copies please communicate with

CHARLES F. BINNS
Secretary, American Ceramic Society
ALFRED, NEW YORK

SAVE FUEL BY PREVENTING HEAT LOSSES

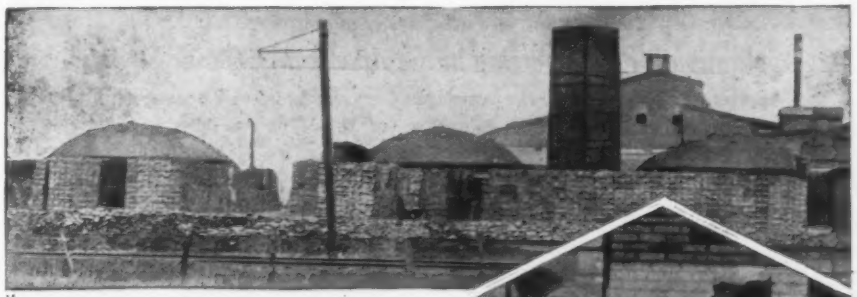
SIL-O-CEL
PATENTS MEAT PENETRATION
TRADE MARK REGISTERED U.S. PATENT OFFICE
MADE FROM CELITE

Has high insulating value. Large covering power due to light weight, making them low in cost. Permanence and durability. Applicable to any surface. Will not disintegrate with heat. Increases the output by making productive the heat which is ordinarily lost in uninsulated equipment.

Write for blueprints and literature.

CELITE PRODUCTS CO.

NEW YORK - - - - 11 Broadway
PITTSBURGH - - - Oliver Building
CHICAGO - - - Monadnock Building
LOS ANGELES - - Van Nuys Building
SAN FRANCISCO - Monadnock Building



4 to 3—Since the Boss Put Browns In!

LASH your production into shape with a Brown Temperature Control—ship four bricks to every three you now load. That's what the boys are now doing around Des Moines, in Illinois, Indiana, Ohio, Canada and Everywhere. One of the big Des Moines District plants is shown above.

Find out how they cut out poor burns and fuel wastes. Write now for full information to The Brown Instrument Co., Philadelphia, or one of their district offices in New York, Pittsburgh, Detroit, Chicago or St. Louis.

Brown Pyrometers
THE WORLD'S STANDARD HEAT METERS

NORTON

Alundum AND **Crystolon**

The modern abrasives which make up the

NORTON GRINDING WHEELS

have played an important part in the evolution of grinding.

Improved methods of wheel manufacture, co-operating with modern research and experimental laboratories, have helped develop a Norton Grinding Wheel of the right grain and grade for every grinding job.

Our experience is at your service in selecting a wheel or solving a difficult grinding problem.

NORTON COMPANY
WORCESTER, MASS.

Alundum Plant: Niagara Falls, N. Y.
Crystolon Plant: Chippawa, Canada
New York Store: 151 Chambers Street
Chicago Store: 11 No. Jefferson St.

(600)

(Send to Chas. F. Binns, Sec'y, Alfred, N. Y.)

Application for Membership in the American Ceramic Society

Approving the objects of the American Ceramic Society, I hereby apply for membership in the Society, and subscribe for the "Journal of the American Ceramic Society." Enclosed find $10.00 for initiation fee and annual membership dues, $4.00 of which is for one year's subscription to the Journal.

NAME ADDRESS DATE

.....

(Send to Chas. F. Binns, Sec'y, Alfred, N. Y.)

Subscription to the "Journal of the American Ceramic Society"

Enclosed find $6.00 in payment of one year's subscription to the "Journal of the American Ceramic Society." Subscription to start with the first number of Volume 2 of the Journal.

NAME ADDRESS DATE

.....

THE ROESSLER & HASSLACHER CHEMICAL COMPANY

—÷NEW YORK÷—

"America's Leading Ceramic Material House"

A mark of distinction emblazing quality solely gained on Merit as THE BETTER GRADE PRODUCTS having a sphere of influence all of their own.

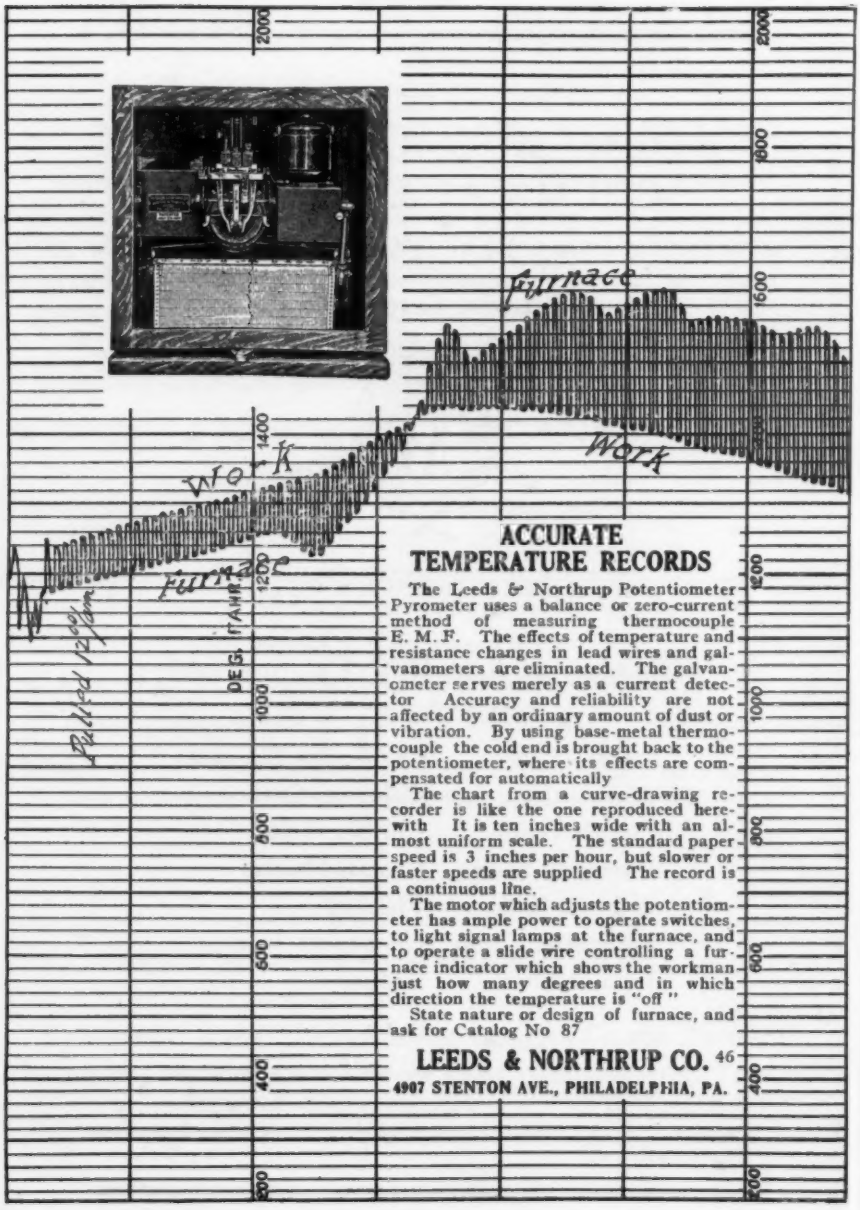
A Number of R. & H. C. Co. Specialties

—A 1—

Oxide of Tin	Carbonate Barytes
Bone Ash	Calcium Carbonate
Cobalt Oxide	Copper Oxide
Cornwall Stone	Crocus Mortis
Enamel Soda	Fluorspar
Powdered Glass	Chromate Iron
Iron Oxide	Kalkspar

Branches

Cleveland
Chicago
Cincinnati
Boston
Philadelphia
Kansas City
San Francisco
New Orleans



ACCURATE TEMPERATURE RECORDS

The Leeds & Northrup Potentiometer Pyrometer uses a balance or zero-current method of measuring thermocouple E. M. F. The effects of temperature and resistance changes in lead wires and galvanometers are eliminated. The galvanometer serves merely as a current detector Accuracy and reliability are not affected by an ordinary amount of dust or vibration. By using base-metal thermocouple the cold end is brought back to the potentiometer, where its effects are compensated for automatically

The chart from a curve-drawing recorder is like the one reproduced herewith It is ten inches wide with an almost uniform scale. The standard paper speed is 3 inches per hour, but slower or faster speeds are supplied The record is a continuous line.

The motor which adjusts the potentiometer has ample power to operate switches, to light signal lamps at the furnace, and to operate a slide wire controlling a furnace indicator which shows the workman just how many degrees and in which direction the temperature is "off"

State nature or design of furnace, and ask for Catalog No 87

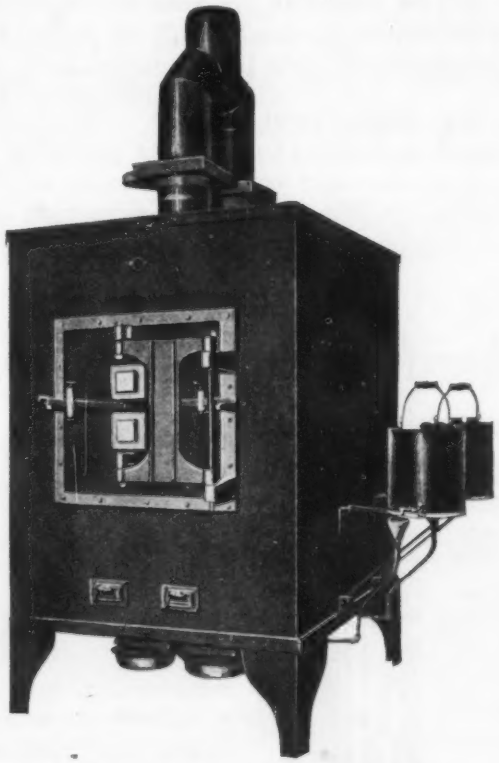
LEEDS & NORTHRUP CO. 46

4907 STENTON AVE., PHILADELPHIA, PA.

PERFECTION POTTERY KILNS

FOR FIRING BISCUIT, CLAY BODIES AND GLAZES.

EQUIPPED FOR KEROSENE OIL,
MANUFACTURED AND NATURAL GAS.



NO. 12 PERFECTION POTTERY KILN
Equipped with Kerosene Oil Burners.

B. F. DRAKENFELD & CO., Inc.

50 MURRAY STREET NEW YORK, N. Y.

ILLUSTRATED CATALOG MAILED ON REQUEST

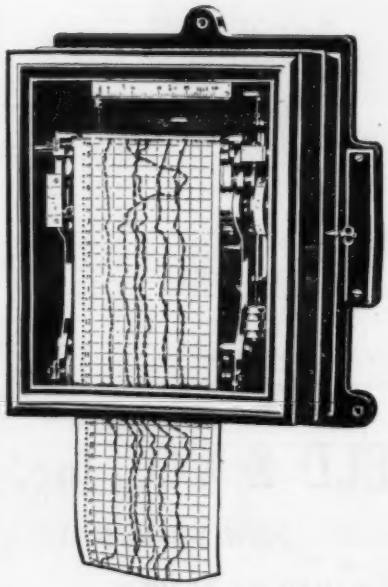
This War Will Banish, Not Only Autocracy But Also Inefficiency and Waste

You will be compelled to conserve COAL because close government supervision over all natural resources will unquestionably continue.

You will be forced to cut your use of LABOR to a minimum because it will be many years before there will again be a sufficiency of help.

On the other hand — there will come a tremendous demand for building products, and the plant manager who is far-seeing is PREPARING NOW so he will be able to turn out a MAXIMUM of good ware at a MINIMUM cost.

Engelhard Le Chatelier Pyrometers



Offer you the best possible means for meeting this situation in the way that will eliminate the "leaks" and make your PROFITS commensurate with your broader activities.

Our expert engineers know the clay field—they can point to many remarkable successes—they can tell **you** what to do to protect yourself against the common enemies — Inefficiency and Waste.

We are Ready to Serve

Charles Engelhard

30 Church St., New York, N. Y.

DRYERS FOR PROFIT

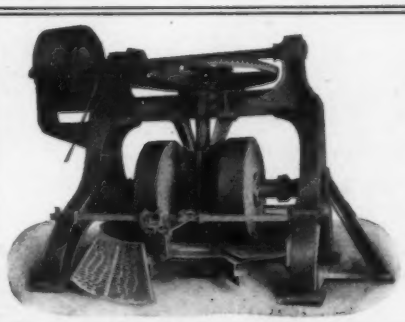
A Proctor Dryer represents the most efficient and economical method of drying. It embodies air recirculation, utilization of exhaust steam. Requires minimum time for drying. Saves floor space, labor, power, etc. The capacity and degree of drying are not affected by weather variations.

"Proctor" DRYERS for *All Clay Products.*

Made by the oldest and largest builders of dryers.
Ask for Proctor Dryer Catalog for your material.

The Philadelphia Textile Machinery Co.
Seventh St. and Tabor Road, Philadelphia, Pa.

CHICAGO, ILL. Hearst Building
CHARLOTTE, N. C. Realty Building
PROVIDENCE, R. I. Howard Building
HAMILTON, ONT., CAN., W. J. Westaway, Sun Life Bldg. 41



American Nine Foot Dry Pan

Here's one of our famous line of pans. They are built to handle a lot of clay and they do it. Nothing shoddy about this pan, that's why it makes good and works steadily without trouble. Get our pan printed matter. We surely have a pan to do your work better and with less trouble and expense than you are now doing it. Let us prove it.

The American Clay Machinery Co.
Bucyrus, O.

J. T. BRAMLETT

HIGH GRADE
PLASTIC FIRE CLAY

A Bonding Material Suitable for Crucibles, Glass Pots, Etc.
Sold Direct to Consumer

ENID, MISSISSIPPI

VITRO CHEMICALS

SELENITE of SODIUM

ARTIFICIAL CRYOLITE
for white and opalescent glass

SODIUM SILICO FLUORIDE

UNDERGLAZE COLORS
for high temperatures

POTTERY GLAZES & ENAMELS

The Vitro Mfg. Co. **Pittsburgh, Pa.**

JOURNAL OF THE AMERICAN CERAMIC SOCIETY

The only technical periodical reaching all branches of the great ceramic industry, (brick, tile, terra cotta, pottery, porcelain, sanitary ware, refractories, glass pots, sewer pipe, tiles, cements, glass, etc., etc.)

RATES

1 page	$40.00	per insertion	
1/2 "	25.00	"	"
1/4 "	15.00	"	"
1/8 "	10.00	"	"

20% discount for 12 continuous insertions

For further particulars address

COMMITTEE ON PUBLICATIONS,
L. E. Barringer, Chairman,
Schenectady, N. Y.

American Ceramic Society, 211 Church St., Easton, Pa.

H&G

H&G OXIDE CHROMIUM

MORE FINELY DIVIDED AND FREER FROM SOLUBLE SALTS

THE HARSHAW FULLER AND GOODWIN CO.

CLEVELAND · NEW YORK · PHILADELPHIA

Let Us Help Solve Your Problems.
The task now confronting the industries of this country is to increase production in order to meet the gigantic demands of a world war, and this must be done with less man-power.
This can be accomplished by the use of more equipment, better equipment and the speeding up of the equipment in hand.
Electric power, properly applied, will do much toward solving this most important and complicated problem. Consult our specialist in your vicinity. His services are yours for the asking.
GENERAL ELECTRIC COMPANY
General Office: Schenectady, N. Y.
SALES OFFICES IN ALL LARGE CITIES 43-60